

UNITED PLANTERS' ASSOCIATION OF
SOUTHERN INDIA

*Davaishola
P.O.
Chilgiris,
India*

TEA SCIENTIFIC DEPARTMENT

ANNUAL ADMINISTRATION REPORT

FOR

1940-41



MADRAS

PRINTED AT THE DIOCESAN PRESS, VEPERY

1941

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OF

TEA SCIENTIFIC
SECTION

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SCIENTIFIC STAFF

<i>Tea Scientific Officer</i>	... J. D. Manning, B.Sc. (Agr.)
<i>Entomologist</i>	... S. Ananda Rau, M.Sc.
<i>Mycologist</i>	... M. K. Subba Rao, B.Sc.
<i>Soil Chemist</i>	... V. Jayaraman, B.A., B.Sc. (Agr.)

U. P. A. S. I.

TEA SCIENTIFIC SECTION

ANNUAL REPORT FOR 1940-41

Staff.—There have been no changes in the staff during the year.

Correspondence.—1,540 letters were received during the year and 1,725 were despatched. These numbers show an appreciable rise over the numbers for last year and reflect an increase in the amount of advisory work by correspondence.

Touring.—A number of tours and visits to estates were undertaken during the year.

The Tea Scientific Officer visited estates in the Mundakayam district during June. A tour was made of part of the Nilgiris in July; in view of the large number of estates in the Nilgiris it was not possible to do a full tour at one time, and the second part of the tour in the Nilgiris was completed in March.

In September a tour was made to estates in the Vandiperiyar and Peermade districts. The General Manager of the Travancore Tea Estates very kindly put a bungalow at the disposal of the Tea Scientific Officer during this tour.

Two short visits were made to the Anamallais chiefly in connection with starting field experiments. Some special visits to estates were also made.

The Entomologist toured as follows :—

April—visit to Anamallais.

June–August—visit to South Travancore.

The Mycologist toured as follows :—

February—visit to High Range.

Special visits to estates.

The Soil Chemist visited some estates.

Publications.—Paper No. 2 (Miscellaneous) was published during the year and distributed to estates.

A series of questions and replies of general interest have been published in issues of the *Planters' Chronicle*.

Experimental and Research Work.—Detailed accounts of experimental and research work which has been conducted during the year will be found in the reports of the Officers. The chief subjects under investigation have been :—

- (1) Study of seasonal variations in the starch content in supply plants and mature tea.
- (2) Field experiments on manuring, pruning of tea, resting tea, and weeding.
- (3) Investigation on losses of nitrogen from organic matter.
- (4) Analytical work dealing with adulteration of tea.
- (5) Studies in the root habit and development of tea.
- (6) Studies on control of *Helopeltis*.
- (7) Estimations on the moisture content of green leaf, and on proportion of surface moisture content.
- (8) Observational studies on shade trees.

Visit to Station of Director of Tea Research Institute of Ceylon.—It was a great pleasure to welcome to the Station Dr. R. V. Norris, Director of the Tea Research Institute of Ceylon. Dr. Norris, who came to the Station in November and stayed a few days, had discussions with all the members of the staff, and during this stay some estates were visited.

Buildings.—All buildings have been maintained in a fair state of repair. The water supply to the Station has for some years been very unsatisfactory, and the building of a new well was sanctioned.

Adulteration of Tea.—At the request of the Tea Section Committee, work has been done in connection with finding means of making a more reliable check on the adulteration of tea. Both the definition of tea and the chemical tests in the present Madras Act are open to criticism. Some 10 years ago, Dr. W. S. Shaw suggested a series of chemical tests which were designed to detect adulteration of tea. It was made clear at the time that the proposed tests had been made only on a limited number of tea samples, and that more samples should be analysed with a view to narrowing the limits then proposed. Accordingly, a large number of analyses have been done on tea known to be pure and tea known to be adulterated. One further series of tests are to be made and when they are finished the final report will be issued. It should be stated that there is no intention, in making new proposals, to improve the standard of tea which can be sold, but merely to give a better definition of tea and to give tests of a chemical nature which will detect adulteration, whatever be the type of adulterant used. Further reference to this subject appears in the report of the Soil Chemist.

Soil Erosion in the Nilgiris.—The Executive Committee of the U.P.A.S.I. offered its assistance when the proposal was made, chiefly on the initiative of Mr. P. W. Davis, District Forest Officer, to form a sub-committee to make a survey of the problem of soil erosion on the small cultivation holdings in the Nilgiris. The Tea Scientific Officer was asked by the Collector of the Nilgiris to serve on the committee. Several meetings were held, and conditions were studied on small holdings. It may be possible to issue a full report at some later date, but meanwhile a most important advance will have been made if the existence of the sub-committee on soil erosion leads to

permanent action being taken to tighten up conditions of alienation of new land, and to take steps to stop the appalling rate at which soil erosion is now going on in the holdings of most small cultivations in the Nilgiris. The problem is complicated, but it is felt that no new research work is required, but that recommendations should be made, based on existing available research work, of those methods which are most applicable to conditions in the Nilgiris. Cultivation of market, garden and other crops has been going on for some years, but has increased greatly during the past 20 years. Unfortunately very little has been done to guide the cultivators on soil conservation matters, and already a great deal of very valuable land has been lost, enormous gullies have been formed, and the fertility of land in cultivation is decreasing at an alarming rate. The problem requires immediate attention, and it is to be hoped that its importance will receive further recognition.

Field Experiments.—During the year a further series of field experiments were laid out and started, bringing the total number of these experiments now being run on estates and with the co-operation of estate managers up to 16. These field experiments deal with a number of different subjects on which it is considered necessary to obtain more precise information under South Indian conditions. There are now in operation experiments to determine the effect on yield of tea of artificial fertilisers. Although work has been done elsewhere on this subject, the annual expenditure on fertilisers makes it desirable to know what return is likely under our particular conditions. Some of these fertiliser experiments are already giving useful results, but until they have completed at least one full pruning cycle it is too early to be sure of such responses as have already been obtained. There are other experiments which are designed to give information on the effect of cattle manure and compost. In all the above experiments the time factor and the method of application are points also under consideration.

A second group of experiments deals with pruning tea, and improvement of tea by resting. Field observations and work now being done on the seasonal distribution of food reserves, in the form of starch in mature tea, has shown the necessity of finding out the most satisfactory way of restoring vigour to plants which have lost vitality.

The experiments are designed to determine :—

- (a) The right seasons for pruning,
- (b) The best height for pruning and tipping, and
- (c) Whether it is better to rest tea before or after pruning.

Pruning type experiments are also being run in connection with *Helopeltis* control.

In another experiment the treatments compared are different kinds of soil tillage. Lastly, an experiment is now in operation from which it is hoped to find out what effect weed growth has on tea at certain seasons of the year.

All these experiments (except three at the Station) are being conducted on estates, and apart from the actual treatment under experiment, the areas receive exactly the same kind of attention as do the rest of the field and the rest of the estate. Particular care has been taken to avoid anything that might be described as an artificial condition, since it is recognised that any results which are obtained must be applicable to commercial conditions.

When it was decided to run field trials on estates, it was realised that many difficulties were likely to occur. It is all the more satisfactory to be able to report now that practically no hitches at all have occurred, and this is very largely due to the fact that those who have undertaken to run field trials with the co-operation of the Department have most creditably carried out a difficult task.

Acknowledgements.—Mr. P. A. Naylor and Mr. A. N. Scott-Hart served as members of the Scientific Sub-Committee up to the time of the annual general meeting. Mr. Naylor has continued as a member of the Committee. Messrs. Eric Johnson, R. Fowke and J. L. H. Williams have also served on the Committee. It was with very deep regret that the staff learnt of the death of Mr. R. Fowke shortly after he had joined the Committee. Very grateful thanks are due to all the above gentlemen.

It is a pleasure once again to thank the numerous Planters who have extended hospitality to the members of the staff.

The staff of the Agricultural College at Coimbatore are thanked for assistance given and for the loan of books.

METEOROLOGICAL

1940-41

Month	Rainfall in inches	No. of days with rain	Temperature		Humidity		Vapour Pressure		Cloud	
			Average Afternoon Maximum	Average Overnight Minimum	8-30 A.M.	3 P.M.	8-30 A.M.	3 P.M.	8-30 A.M.	3 P.M.
April '40...	3.48	10	82.7	64.3	85.5	48.6	22.4	22.6	3.7	3.8
May „ ...	3.09	12	86.6	66.4	89.0	78.6	23.9	25.5	3.9	6.1
June „ ...	19.91	19	77.5	64.8	92.2	87.0	22.9	23.8	6.5	7.6
July „ ...	18.19	30	72.2	64.4	97.0	90.0	22.4	23.8	8.7	8.7
Aug. „ ...	15.18	30	73.9	63.2	97.4	92.7	22.4	24.0	7.4	8.0
Sept. „ ...	5.35	22	75.5	63.5	93.4	84.1	22.8	24.5	3.2	5.7
Oct. „ ...	3.35	17	79.0	64.7	89.4	79.9	22.2	23.8	3.1	4.3
Nov. „ ...	7.19	20	75.8	63.5	97.3	79.7	22.8	23.0	6.1	5.8
Dec. „ ...	0.50	4	76.3	55.5	93.1	68.9	18.6	19.9	2.2	3.7
Jan. '41...	0.06	2	80.3	57.8	89.4	53.0	18.1	17.5	0.8	2.0
Feb. „ ...	...	...	84.5	57.6	74.5	51.6	18.3	18.7	1.0	2.2
Mar. „ ...	...	2	87.3	62.4	82.0	49.2	20.8	19.5	...	1.2
Total ...	76.30	168								

Meteorological—Rainfall for the season was less than last year by 1.82 inches and was still below average. The number of days with rain, however, showed an increase over last year by 17. The N. E. monsoon was light, the month of October registering only 3.35 inches as against 13.23 inches in 1939-40.

AGRICULTURAL

Introductory Note.—This report differs from earlier reports under the heading 'Agricultural' in that it includes some notes and impressions on the agricultural aspect of tea planting which would not ordinarily be included in an annual report, but are included in this report as circumstances make it convenient to record a summary of general notes which have been collected during the past 3 years. The notes which are here included are a summary only, as the subject matter covered is too wide to permit of greater detail. Most of the subject matter under all headings records observations which have been made during visits to estates, and deals particularly with questions which have arisen in correspondence and discussions. Only matters which are considered to be of general, rather than particular, interest are included. It was originally intended to publish as a Paper the notes which are included on soil erosion. But the subject matter would have to be somewhat extended, so it has been found convenient to include in this report a briefer summary of data on soil erosion.

Investigations on the Rooting Systems of Tea.—Some further work has been done on investigations on the rooting systems of tea, during the past year. So far all the work has been done on tea growing in the typical soil types of the Nilgiri-Wynaad. The work is far from complete, but it may be well to record such observations as have been made.

It was necessary in the first instance to get a general idea of the extent and shape of tea roots. This was done by making several excavations of the whole root system of mature tea. The investigations were carried out on tea 10–12 years old, and it was found by the excavations that the tap root penetrates to a depth of up to 12 feet. The soil was a fairly stiff one and it would therefore seem that tea roots are capable of penetrating stiff layers of clay, and it is now very much to be doubted whether the generally held opinion that tea roots are incapable of forcing a passage through stiff soils holds good. This is more so, since fine feeding rootlets were found at the greatest depths, and very small laterals had developed up to 3 feet lateral distance from the lower end of the tap root. The evidence goes to show that the lateral and downward spread and development of tea roots take place relatively easily in the stiffest soil types, although it is admitted that the thickest laterals branched off the main tap root in the region of the planting holes (in which it appeared a blacker loose jungle soil had been used), and except in this area no large-sized laterals (more than 1 cm. in thickness) had developed. Observations indicate that the fertility, and more particularly texture, of the soil in the planting holes has a bearing on the future development of the bush, and in view of the mass of root development which had taken place in the region of the planting hole, there are reasons to suppose that the use of the very best soil available for filling planting pits has much bearing on the development and future thriftiness of the plants.

The excavation work further showed that the extension of laterals from the main tap root continued outwards to about 5 feet from the main tap root up to the first 18 inches in the soil, and below that depth the laterals extended only a little less far. Laterals and feeding roots were found in abundance up

to the depth reached by the tap root. During the dry weather the soil up to 15 inches was found to have dried out almost completely, and no active root development could be found. There appeared to be no die-back of the feeding rootlets, though they were dormant. In the lower soil horizons, however, where moisture remained, the feeding rootlets were active and some new development was noticed. These observations show that the tea bushes are capable of absorbing moisture and nutrient material from the deeper layers of the soil in the dry weather, and account for the ability of the bushes to continue flushing during the most severe droughts provided the soil is deep and sufficiently well drained (hence sufficiently aerated) to allow of root development to the deep soil horizons. They also suggest that, given a deep soil, there should not be much permanent drought damage provided the soil is well drained. Drought damage has been noticed in deep soils, but usually there was ample evidence, from the configuration of the land, that the water table was too high during the rainy period, and this would have precluded deep root penetration. Drought-killed bushes on such areas show a typically shallow root system. An examination of the depth of the root system can give an idea of the state of drainage, and the only remedy in such cases is the construction of deep drainage works. Where such work has been done it has given excellent results and the earlier yellowing of the tea has been less noticeable.

In order to determine the distribution of the feeding roots in the various layers of the soil, equal and representative samples of soil were taken from various depths. The roots were placed end to end on sheets of paper and secured by gum. This method gave a figure in length and it was found to be most useful, but the method takes so long to complete that it is not possible in this way to make many recordings.

Converting the figures into percentages the following root distribution was found :—

<i>Soil Depth</i>		<i>Per cent Roots</i>
0-4"	...	6.0
4-8"	...	20.4
8-12"	...	19.0
12-16"	...	10.2
16-20"	...	6.4
20-24"	...	4.0
24-28"	...	9.5
28-32"	...	14.5
32-36"	...	10.0

A second method adopted was again to take equal weights of soil between different horizons in the soil. The roots were separated from the soil by washing and then dried and weighed. By this method the following root distribution was obtained :—

<i>Soil Depth</i>		<i>Per cent Roots</i>
0-1 ft.	...	54
1-2 "	...	14
2-3 "	...	9
3-4 "	...	11
4-5 "	...	7
5-6 "	...	5

The above recordings show clearly the extremely good distribution of the roots in the various soil horizons below 1 foot depth. The fact that over 50% of the feeding roots are in the first foot of soil is illustrative of the care which is necessary in tillage operations.

The greatest activity on the part of the roots, as measured by new root development, was found to take place after the early rains following the dry weather, and again at the end of the S. W. monsoon. This might well be explained by the fact that at these periods both moisture and temperature are optimum for development and growth, whereas in the dry weather lack of moisture is a limiting factor, and during the S. W. monsoon excess moisture and lack of aeration probably account for less intensive activity. It was noticeable that during the monsoon months the new roots which developed tended to curl up towards the surface. This upward growth movement is accounted for by lack of aeration and is an effort on the part of the roots to obtain more air by growing towards the soil surface.

On an analogy with other crops it is not impossible that final yield in tea is dependent on the amount of nutrient absorption which takes place at the time of greatest activity on the part of the rooting system. The observations made show that the greatest activity is confined to two short periods in the year when moisture and temperature are optimum. Roughly those seasons are April-May and September-October. The root observations then turn out to be of very great importance in relation to cultivation and manuring. If cultivation results in damage to the feeding roots, as it undoubtedly does, it is concluded that tillage operations should not be done during the above-mentioned periods, and if they are to be done at all, some other season of the year must be found. Similarly, the greatest benefit from manuring is likely to occur if the manures are so applied as to be made available to the tea during these critical periods of root growth. These and the earlier illustrations made, do perhaps, show how important it is to find out a lot more about the root systems of tea in order that we may best fit in the cultural and other operations.

If possible these studies will be continued, as it is felt that only with more knowledge of root habits and distribution of tea can a real advance in agricultural practice on tea plantations be made. It is for instance highly important to find the response on the part of the root system to such operations as weeding and pruning; some preliminary work with this end in view has already been done, and the method used is to dig a trench 7 feet deep and 6 feet long between bushes in two rows. In the trench a glass frame has been fitted over which there is a cover. The panes of glass are each 11" square and can be taken out when observations are to be made. The first frame has now been in position for 2½ months, but apart from the initial observations nothing of importance has been recorded except some feeding root development in lower layers, as the long dry weather has prevented root development near the surface.

Pests and Diseases.—Pests and diseases are fully dealt with in the reports of the Entomologist and Mycologist. Although no new insect pests or fungal diseases of major importance have been reported for the first time during the year, it was clear that the very heavy and prolonged monsoon which occurred in almost all districts intensified damage from some of the agencies which occur every year. This was particularly so in the case of *Helopeltis*, and the monthly returns which many estate managers have been good enough to send in giving details of the incidence of the insect showed that in 1940 although

attacks started late, they were very severe, and the period of incidence continued later than usual. The attack, indeed, has been well described as a 'blitz'. The Entomologist spent several weeks in S. Travancore continuing his investigations, and the pruning and tipping experiments which were laid down over a year ago have been continued. It is still too early to give definite views on the connection between *Helopeltis* and pruning method though the indications are that the higher types of pruning assist the tea bushes in recovering from attack and ensure that less damage is done lower down in the bushes.

Replies to a questionnaire which was sent out to estate managers have given us the advantage of having the personal views of several managers on the habits of *Helopeltis*; all this information was summarised by the Entomologist and a commentary given thereon, in an article which appeared in the Tea Section Paper No. 2. The problem is continuing to receive close attention, and it is intended to arrange that the Entomologist will spend a further period in S. Travancore during the coming year, since it is felt that even if no strict control seems possible at the moment, it is nevertheless of much importance to investigate all possible methods which might lessen the effect of attacks.

Termites attacking Red gum seedlings caused considerable damage to new clearings during the year, and in some cases almost 100% of the plants was destroyed. Several methods of control were suggested in an article on the subject which appeared in Paper No. 2, and it is expected that trials with these methods will be tried out in the coming year. Chief among the difficulties is that though casualties are greatest in very young plants yet 2- and 3-year old plants are attacked, and as a result, the advisability of planting Red gum in high land is questioned. There have been no reports of damage by Termites to Red gums planted in swampy areas. It will probably be wise to select an alternative fuel tree for planting in non-swampy land. Among trees suggested for this purpose is *Cassia siamæ (florida)* which has distinct possibilities at all except the higher elevations.

The leaf-fall disease of Grevilleas, known as *Phyllosticta*, has for some years been occupying the attention of estates and of the Scientific Section. As a result of observations made it is now considered that this fungal disease is not a primary cause of leaf-fall or general unthriftness of Grevilleas though some further work on the subject is required. Observations show, however, that unthriftness of Grevilleas is much more likely to be due to damage by wind, to poor soil conditions, to climate (heavy rainfall followed by a long period of drought) and to aging of the trees. Cankering and a physiological condition known as gummosis are contributing causes of weakness in Grevilleas. The leaves are known to be attacked by *Phyllosticta* and *Cercospora* sp. and also by Red Spider. These latter agencies in themselves are not now considered responsible for severe damage, though they may be factors which accentuate the damage from other causes. Observations continue to show that where Grevilleas are in areas reasonably well protected from wind, in good soil, and where climatic conditions are not too severe, they have suffered comparatively little from leaf-fall and continue to be thrifty. There is some reason for believing that Grevilleas can be kept in the best condition by pollarding when they are still young (up to 15 years).

The Black Rot leaf disease of tea was more widespread and damaging than usual, during the past year. This is largely attributable to the climatic conditions, but the time has certainly arrived when control measures should

be fully investigated. The disease occurs in N. E. India and the Tocklai Station have been good enough to give us the benefit of their data. Experiments for the coming year are planned and it is expected that they will be carried out in the Anamallais.

Belworm continues to cause casualties in tea nurseries. The best chance of reducing damage would appear to be in the case of basket plants, and a method of preventing attacks which has been suggested is pre-heating of the soil to 60°C before the baskets are filled. The method has been tried out and seems to be giving encouraging results. The usual method of pre-treatment is to heat the soil by placing it on a tagrum and lighting a fire underneath.

Finally, a word about the root disease, *Rosellinia*. A fuller description is given in the report of the Mycologist of steps which were taken to deal with *Rosellinia* on an estate in the Nilgiri-Wynaad. The percentage of bushes found to be infected was very high in several fields, but fortunately the disease was discovered in its early stages, and by careful treatment of individual bushes it is most satisfactory to record that the large majority of the bushes have been saved. This is perhaps the first large scale attack by root disease which it has been possible to cure, and the manager of the estate concerned is to be complimented on the thoroughness with which the work of treatment was carried out. Many hundreds of infected bushes were saved and are now in full health.

The above, then, have been the main pests and diseases on which it is necessary to comment here; further details and reference to other pest and disease problems will be found in the separate reports of the technical officers.

Losses of Nitrogen from Organic Matter.—Many planters are anxious to know whether organic matter which is available for application to tea land should be forked into the soil, or whether just as good results are obtained by leaving it lying on the soil surface. This is a question very closely connected with general management, particularly soil tillage. As the value of organic matter is partly—but not entirely—dependent on its nitrogen content, it is necessary to know what happens to the nitrogen in both cases, and which form of management allows of the greatest accumulation of available nitrogen in the soil with the least losses.

The only really satisfactory method of solving the problem is by field trial, but it was thought useful as a first step to conduct laboratory experiments which might give some clues. Experimental work was accordingly started, and the results obtained in the first part of the work are to be found in the report of the Soil Chemist.

The initial experimental work in which *Grevillea* leaves, tea leaves and dadap leaves were used goes to show several important facts. It is clear, for instance, that the losses of nitrogen which occur, presumably chiefly in the form of gaseous nitrogen, depend on the type of material used and the climatic conditions under which this material is decomposed. The lower the carbon/nitrogen ratio of the organic matter, the greater the losses of nitrogen which take place. For example, a large part of the nitrogen in dadap leaves, which contain a high proportion of nitrogen and have a low C/N ratio, was lost in gaseous form, while practically none of the nitrogen in *Grevillea* leaves, which have only a small percentage of nitrogen and a high C/N ratio, was lost. Losses depend on the type of material which is used,

Again, losses of nitrogen appear to be greatest under climatic conditions typical of the N. E. monsoon when there are alternating periods of wet and dry weather.

Experience with the early experimental work has shown that some change in technique is required, for unfortunately there was no exact approach to field conditions. Thus, although in some cases the organic material was laid on the soil to represent a mulch, yet in other cases, although material was mixed with the soil, the proportion mixed was too high to represent anything like practical conditions. This will be remedied as the work continues. The early indications, however, would seem to show that nitrogen in organic matter can best be preserved if the material is incorporated in the soil. For, when dadap leaves were mulched, 46 per cent. of the total nitrogen was lost and 16 per cent. converted into nitrate nitrogen. When these leaves were mixed with soil, 4.8 per cent. of the total nitrogen was lost in gaseous form, and 11.2 per cent. of nitrate nitrogen was formed. Thus, while more was lost by mulching, yet less nitrate nitrogen was formed by mixing with soil. This obstinate result further complicates matters, and shows the necessity for both field and laboratory trials.

Perhaps the most interesting result obtained so far is that which shows both in the case of dadap and tea the regularity in time in which nitrate nitrogen is formed under the particular climatic conditions in which the experiments were carried out. In all the analyses done, nitrate nitrogen occurred, somewhat suddenly, at about 45 days after the start of the experiment. This result may eventually prove to have an important practical application affecting the season for applying organic matter.

At the moment it appears that there is not a great deal to be gained by way of nitrate nitrogen in forking in organic matter provided there is no soil erosion and although one's natural preference is to fork in green material or compost or cattle manure provided there is sufficient quantity of it to justify the expense of forking, and provided there is a long interval between successive forkings, yet the gain may be only small particularly if we consider the value of a vegetable mulch on the soil surface.

Compost and Cattle Manure.—Enquiries on this subject have chiefly been concerned with what is now an old problem, viz., what material should be composted and what material is suitable for direct application to the soil. It seems clear that a set of rules for guidance would be helpful, and replies to enquiries of this nature have listed general rules, for which it was found necessary to pay particular attention to the time factor. The following are the suggestions which have been made:—

(a) All green material which is hard and coarse and of low C/N ratio is unsuitable material for direct application, but has an appreciable manurial value if it is composted. This applies to material such as grass, bracken, lantana cuttings, etc., which before they can be decomposed require extra nitrogen, and it is considered advisable to supply this extra nitrogen before the material is applied in the field, lest, in course of decomposition in the soil, nitrogen which ought to be available to the tea crop, should become temporarily immobilised.

(b) Green material of whatever nature which is available from outside the tea area can most conveniently be preserved for use as manure in the compost heap, if it happens to become available at a time when it is either inadvisable or inconvenient to apply such material direct to the field. For

example, it is probably wasteful of the nitrogen in such material to apply soft green material after the start of the S. W. monsoon, as soil conditions then are not ideal for decomposition and part of the nitrogen may be leached out in the drainage water. Far better to add this material to the compost heap and preserve it for application after the worst of the S. W. monsoon is over.

(c) Similarly, cattle manure which becomes available during the S. W. monsoon or dry weather should not be applied straight away, but should be kept in heaps or in the compost heap for application at more suitable seasons, i.e., at the beginning of the early rains or after the worst of the monsoon is over.

(d) If cattle manure supplies are limited but green material is available, the best use of this cattle manure can be made by mixing it with the green material to make compost. It is the one means of turning such green material, particularly coarse material, into good bulk manure.

(e) In using bulk manures, consider the season of application. The chief thing is to avoid losses which occur by monsoon applications. Bulk material which is mature and well decomposed can be applied at almost any time except during the heavy rains.

(f) The process of composting has two special values. It is a means of making good manure out of poor material, and it is a means of storing all waste material until the best season for application.

Manuring with Artificial Fertilisers.—Advices have been given during the year on a number of manuring programmes, and a considerable revision of the type of mixture used has been suggested on account of the change in prices of different kinds of fertiliser. All the imported fertilisers generally used, such as sulphate of ammonia, superphosphates and muriate of potash, have risen very considerably in price and in some cases now stand at about double their pre-war level. On the other hand, fertilisers which are produced in India have shown no marked rise in price, and in some instances are considerably cheaper. By taking into account the cost per unit of fertiliser delivered on the estate, it has been possible to work out mixtures containing the same amounts of plant foods at prices which approximate to those relating to two years ago. It seemed probable at one time that the price of fertilisers would reach prohibitive levels, but this has not occurred, and the development of the fertiliser industry in India is some assurance that estates will be able to continue with their programmes.

Nurseries.—During the year a paper dealing with nurseries has been in course of preparation, and it is expected that this paper, the third in the series which it is proposed to issue, will be available within a short time. The whole aspect of nurseries from the agricultural and pest or disease viewpoints is discussed and particular attention paid to points which have been dealt with in advisory work. The problem of watering the nurseries during the dry weather has arisen on many occasions, and experience would indicate that it is in respect of watering that great improvements can be made in nurseries, since it is clear that over-watering has been the cause of many troubles. It is the opinion of the Department that in the majority of cases nursery plants are over-watered, and that one effect of this has been poor development of the roots leading in some cases to root-rot commonly referred to as 'bitten off' disease. The suggestion was accordingly made that watering of nurseries should be restricted to 2 or 3 waterings a week instead

of a daily watering. This suggestion has been carried out in nurseries which were inspected during the height of the dry weather, and observations on the development of the plants clearly indicate a considerable improvement in development of the aerial parts and roots as a result of the less frequent waterings. It is therefore considered advisable that watering should be cut down and only sufficient water given to keep the soil just moist. The number of waterings required depend largely on the type of soil and the shading of the nursery, but experience soon shows how often it is necessary to water the beds to keep them moist and not continuously wet. Particular care is required in the case of basket plants, since the baskets on the outside of the beds are liable to dry out a little more rapidly than the inner baskets.

In baskets filled with soil containing a high percentage of silt and clay it was evident that with frequent waterings the small soil fractions were washed towards the bottom of the baskets and this seriously interfered with root development. This effect has not occurred where watering has been infrequent, and a mechanical analysis of the soil in different layers of baskets has been found to be very much the same.

Where the moisture content of the soil in nurseries is kept on the low side it seems to be the tendency of the plants to develop a bigger root system in search of water. This is all to the good. It should also be remembered that the apparent danger of damage to plants by under-watering is largely offset by the capacity of plants to secure sufficient water in soils which appear almost dry. Experience with forest nurseries confirms the view that far more damage is done to young plants by over-watering than by under-watering, and it is recommended that those concerned with nurseries should try the effect of reducing the number of waterings.

Trouble is sometimes experienced in raising those plant species which have very small seed, and this has several times been overcome by using cans with very fine roses.

Cultivation.—Several enquiries have again arisen in connection with cultivation in the form of tillage operations. These enquiries have related particularly to the problem of the most suitable cultivation methods for backward areas of tea, and whether it would not be of more value to devote less attention to routine cultivation of the better fields and spend more money on cultivating the soil in fields where the growth of tea is poor. The suggestion has been made, for instance, that money can be better spent on making renovation trenches in poor areas than on ordinary forking over larger areas.

It should be mentioned at the outset that no form of cultivation can do any good at all if there is some limiting factor to growth and development of the plants which is entirely unconnected with the physical state of the soil. For example, a poor condition of the plants may be due to such limiting factors as wind damage, poor drainage and waterlogging, inherent or induced poor physiological condition as the result of combined bad pruning and bad plucking, and insufficient acidity of the soil. If any of these, or a similar factor, is responsible for the backwardness of the plants, the cure is certainly not to be found in any changed method of soil tillage, and no amount of cultivation or indeed manuring will lead to improvement until the limiting factor is rectified—if it can be rectified. Soil tillage in any form can only lead to improvement if the ultimate cause of unthriftiness is the physical state and fertility level of the soil.

Further, it may be said that most of the S. Indian tea soils are sufficiently 'loose' and open so that no special tillage is required by a crop such as tea. Add to this the fact that soil stirring is a measure which intensifies very considerably the rate of oxidation, and hence destruction of organic matter, and the problem assumes further importance; for the organic matter of our soils is limited and anything which increases its rate of destruction is suspected as a form of good management. The result of soil tillage is likely to be observed due to the fact that oxidation of organic matter sets free available nitrogen. This sudden freeing of available nitrogen may well show a quick good result and lead one to suppose that forking is beneficial. But this may be misleading since this result cannot be achieved year after year, and it is well to base one's judgement on the fact that in the long run over-tillage can seriously deplete the natural fertility of the tropical and sub-tropical soils in which chemical processes proceed at a rate 6 to 10 times quicker than in temperate climates. Any temporary improvement which may appear will, in the end, be more than offset by a corresponding lowering of fertility.

The effect of forking on the root systems should also be considered though it is extremely difficult at this stage to assess what harm may be done and to what extent a beneficial effect is likely. Present knowledge would indicate leaving the root system undisturbed during periods of growth and development of the fine feeding rootlets which is most pronounced during the early rains in April/May and again when somewhat similar climatic conditions prevail in September/October.

All the evidence suggests that the positive good results from surface soil tillage are unlikely, in most tea soils, to compensate for dangers that may arise, particularly the danger of depleting the organic matter content in the soil. As has been mentioned in earlier reports however, it is impossible to generalise, but it appears that the heavier soils of high clay content and in which grass is ever a pest, may need more cultivation.

On the other hand, in poor or worn out soils where the level of fertility has dropped to the extent of being reflected in unthrifty growth a long term programme of trenching is a form of culture, and possibly the only one, unless large quantities of bulky manure are available, which has prospect of effecting a semi-permanent increase in the level of soil fertility. Trenching or pitting may be based on various systems but the common one is to dig trenches of about 18" - 24" depth and fill these up with new soil or organic matter. Over a long period the major part of the field becomes treated in a way which produces a new and fertile top soil which, incidentally, is of optimum physical condition. In digging these trenches a lot of root damage is unavoidable, but the prospects suggest that this damage is offset by an improvement in the fertility level. Trenching, on a carefully prepared plan, would then seem to offer the best possibility of renewing the top soil, and for backward areas there is much to recommend this form of cultivation, provided always that the soil condition is the limiting factor to growth and is the cause of unthriftiness.

Resting Tea.—A problem which is of general importance in S. India concerns the possible methods of improving weak bushes by resting. It has been found that unthriftiness in tea is closely connected with depletion in the amount of food reserves in the form of starch which is present in the aerial parts and, more particularly, the roots. A depletion in starch reserves means that more has been taken out of the bush than it has been able to balance by intake of

nutrients and consequent starch formation. It is worth remembering that the manufacture of starch takes place in the leaves from where it is transferred to other parts of the bush, and that the most efficient leaves are the young ones. Therefore, continuous plucking of the young leaves reduces the efficiency of what might be termed the plant's factory, and this explains the benefits which are known to occur by lighter treatment. Reduction in the food reserves of the plants is further induced by too short a plucking round in seasons when growth is slow, and by pruning tea after a period of hard flushing when it has used up, by producing the flush, a large proportion of what reserves were stored up. Starch reduction may also be caused by disease which destroys or lowers the functional capabilities of the leaves. *Helopeltis* and Black Rot, for example, prevent the proper functioning of the leaves and this is reflected in a reduction of food reserves in the bushes as a whole. *Helopeltis* is the more serious since the younger leaves are always the first to be attacked. Once the starch reserves have been depleted it is impossible for a plant, except under very favourable conditions and treatment, to accumulate a satisfactory level of reserve unless it is thrown out of plucking and given the necessary rest.

The question which now arises is how this resting should be done. Preferably the bushes should be treated on their own merits, and there seems little advantage in throwing whole fields out of plucking when a reasonable percentage of bushes is in good condition. If selection of individual plants for resting is adopted, no appreciable drop in crop is found since the weak bushes give only a small fraction of the total crop. The method further allows many more bushes to be rested at the same time since no whole large areas are out of plucking.

Secondly, attention must be given to the fact that it is the young leaves that are the most efficient manufacturers of starch, and therefore new leaf growth must be induced; this is best done by pruning, which, provided the plant has enough energy to recover from pruning, must be regarded not as a shock to the bush but rather as a stimulant (it is one object of pruning to stimulate a plant to new growth when it has become worn out).

On these grounds it is suggested that improvement of tea by resting can best be achieved if the following points are considered :—

(1) Prune the bushes and allow them to rest from plucking with their new foliage after the prune, but do not prune after a period of rapid growth which depletes the food reserves in the roots. The best recovery from pruning will always be obtained if the plants are pruned towards the end of a period of slow growth.

(2) If the bushes are very weak it will be an additional advantage to throw them out of plucking for some months before they are pruned.

(3) The selection of bushes for resting is best made about tipping time. As a rough basis of selection all bushes which have been slow to recover from pruning and which look weak should not be tipped. Once the strong bushes have been tipped, there is no need to mark the weaker ones, which, by being left untipped, mark themselves.

(4) If a rested bush responds to its treatment and shows sufficient improvement, there is no point in giving it a prolonged rest, and it should be brought into plucking. No further good result, it seems, can be obtained by resting a bush after it has reached a stage at which it looks as though it will stand up to the usual plucking round. It has been observed that bushes

pruned and rested have shown a marked improvement, but have tended to become 'thin' again when the rest period has been extended for 2 or 3 years. Selection of bushes to bring into plucking could, for instance, be made at 6 and 12 months after the first tipping.

It is expected that still further light will be thrown on the problem of resting when the work now being done on starch content and distribution in mature tea has proceeded further. The work on starch content is designed to determine the periods when starch content is at its maximum, and further to determine the differences in starch content which arise from different treatments. The work is being done partly in conjunction with field experiments in which the effects of resting before pruning and after pruning are being studied.

The starch or food reserve problem happens to be of particular importance in S. India where the climate allows of plucking throughout the year, but is also such that between periods of slow growth occur periods of extremely heavy flushing. These rush periods are in all ways unfortunate and an additional effect is a severe strain on the bushes. This drain on the plant reserves would not occur in a more even climate where the percentage of crop produced each month shows less wide differences than it does in S. India.

Weeding.—In the case of several crops it has been established that the final yield is in proportion to the amount of plant nutrient which is available at certain periods in the development of the plants. A particularly interesting example of this resulted from the work of Clarke on cane sugar who found that final yield was in proportion to the amount of mineral nitrogen present in the early stages of growth, and by arranging the cultivation and manuring programme so that nutrient was ample at this critical period very considerable increases in yield were obtained. A result of this kind is well known to occur with other crops, and it is not inconceivable that something of the same nature may apply to tea grown in the peculiar climatic conditions of S. India. Preliminary studies in the root habits of tea suggest that the chance of there being initial periods of nutrient intake should be explored. In other paragraphs the suggestion is made that tea roots are particularly active at two periods of the year—April/May and September/October when somewhat similar climatic conditions prevail.

The connection between this and weeding may at first sight seem somewhat remote. But two points arise—firstly, when weeds are allowed to grow in tea there is bound to be competition for the available nutrient supply; secondly, the occupation of the soil by a mass of rootlets is known to inhibit nitrification. It must consequently be extremely doubtful, not only from the point of view of yield in crop but from the point of view of the general condition of the tea plants (since yield and condition are inseparable), whether the strain imposed upon the tea plants by the presence of a fairly heavy weed growth at these seasons is not harmful. In order to test the effect of allowing a fairly dense weed growth in tea during April/May and September/October, an experiment has been started in which plots of one treatment are kept practically clean weeded during these periods, with normal weeding during the rest of the year, and in the second treatment normal weeding which permits of weed growth at these periods is allowed. The experiment should give a most valuable result, and if a significant difference in yield is obtained in favour of an approach towards clean weeding at special periods, important data will be available relating

to the effect and control of weeds in tea areas. The practical difficulties of altering the weeding programme, particularly in regard to labour and the amount of weeding which is done at different times of the year, is realised. Nor is sight lost of the importance of a cover of weeds as an anti-erosion measure. Nevertheless, it may be possible to deal with these difficulties if it should be proved that the well-being of the main crop is dependent to a large extent on a more controlled weeding programme.

The value of cover of soft weeds in other seasons and particularly during the heavy rains of the S. W. monsoon when tea roots appear to be less active is not questioned by the hypothesis under consideration, especially as the weeds seem to immobilise and store soluble nitrogen, which might otherwise be leached out in the drainage water, for use by the main crop later on. The value of a crop of weeds is undisputed and no suggestion is made that weeds should not be allowed in tea provided they are the right kind of weeds and grass is excluded, but it appears that more exact seasonal control of weeds might lead to improved management. It is a question of harmony between two crops grown in association to which further reference is made in the section on green manuring.

Pruning.—The seasonal fluctuations in the starch content of mature tea, which are apparent from the results obtained in the present investigations into this subject, have a considerable bearing on the time of year for pruning tea.

The distribution of the crop throughout the year is necessarily a chief consideration in deciding on the pruning programme, and the time of pruning is also governed by the amount to be done and the labour available. A factor which must be considered, however, is the relation between time of pruning and the effect on the bush; this relation is now under study by making starch estimations in the roots of mature tea, and is being further studied by field experiments. The information obtained to date shows that the two heavy flushing periods which occur just before and just after the S.W. monsoon drain the carbohydrate content as found in the roots of mature tea, and as a result, carbohydrate—or food reserve—is at its lowest following these two flush periods. This means that the plants are then in their weakest condition, and a prune may result in death or die-back of the pruned branches, and in a slow recovery from pruning. In the periods of slower growth and slower flush which follow the fast-growing periods the bushes are enabled to recuperate their carbohydrate content, and at the end of a period of minimum growth, reserves of carbohydrate, on which the bushes depend when pruned and until new foliage is formed, are at their peaks. Recovery from pruning is naturally dependent on the condition of the bushes at time of pruning, and it now seems clear, with the known variations in carbohydrate content, that in deciding on time of pruning it is necessary to take into account the carbohydrate supplies in the roots and to avoid pruning in the 6 weeks or 2 months following periods of heavy flushing. (The best analogy which can be found is the case of the potato. The seed potato contains all the food reserve from which the new plant develops and on which the plant depends in the first growth stages for its 'food supply'. If the plant is dug up later on the seed tuber is found to be a sodden wet mass—all the starch has been drained in the development of the leaf parts. The new leaf formed later becomes the factory which produces the food reserve or starch of the new crop of potatoes). On these grounds alone the periods mid-May to mid-July and mid-September to the end of November would be the least suitable times to prune tea under the climatic conditions of S. India. The most favourable recovery could

be expected by pruning in the interval just preceding the heavy flushing times.

In those districts where *Helopeltis* attacks occur the problem is made more difficult since the periods of expected attack also influence the time of pruning, it being highly desirable to avoid *Helopeltis* attack on tea foliage as the bushes are making fresh growth after pruning. In this connection it is of some interest to find that many planters are convinced that pruning before heavy flush periods, although it means the loss of the coming flush, gives so much better recovery from pruning that in the final yield there is an increase and not a loss in crop and the bushes are maintained in a very much better condition.

Wind damage to Tea.—A survey of the problems dealt with would not be complete without reference to damage which is caused to tea by wind, for it is to be doubted if there is any one factor which checks growth and cropping capacity of tea in S. India more than the strong winds, usually seasonal, to which all but the best protected areas are subject. If evidence be required for this conclusion it is readily found. Not only is it well known that once the winds start there is a sudden drop in crop in the following weeks, but all planters are aware that those parts of their estates which are subject to strongest winds are invariably the most backward. There is always a very pronounced difference in the appearance of tea in sheltered and exposed aspects, and this is a feature which stands out perhaps more clearly than anything else when one visits estates in the different districts. The poorness of hill tops is often due to the same cause.

Although it is undoubtedly one of the immeasurable advantages of shade trees that they afford a degree of protection, any improvement in the spacing or arrangement of shade stand will hardly be sufficient for the worst affected areas; in such cases the writer is convinced that real improvement in the tea is dependent on the establishment of adequate wind breaks.

As a first step it is suggested that across the direction of the prevailing winds 3 adjacent rows of tea bushes be allowed to grow up at more or less even intervals. For example three rows might be left every 25–30 rows. The necessity for leaving as many as three rows is that the outer row affords protection for the inner rows. The tea thrown out of plucking in this way represents a fair percentage of the whole, but it is not doubted that any loss of crop will be compensated by the added wind protection.

As a second step it may be necessary to plant hedges, again across the direction of the prevailing winds, of any available plant which grows to sufficient height and is wind resistant. The establishment of thick hedges at relatively close spacing will ensure further protection.

The final step involves establishment of tree wind breaks, which will form more or less permanent wind protection. With both hedge and tree wind breaks it may be necessary to remove a row of tea bushes here and there, particularly after the wind breaks have become established, but here again the protection given to tea between the breaks will compensate for any loss of crop which might occur.

The direction and closeness of spacing of wind breaks will depend on the configuration of the land and the direction of the winds, and in some cases, it may be necessary to resort to squares instead of one direction breaks.

The whole problem of protection from wind, while admittedly a difficult one, does appear to be a basic cause of low production capacity over large areas in S. India, and it is considered that it is one of the major problems to be tackled. Tea is a crop which will not thrive if continuously damaged by wind—no amount of fertiliser or any other treatment can possibly do good unless there is sufficient protection. Unfortunately one cannot measure what damage is caused by wind except by observation and a comparison between protected and wind-blown areas. These latter, however, are sufficient to establish damage of this kind as a limiting factor to growth of tea, and as such it becomes a major agricultural problem.

Backward Tea Areas.—A high standard of evenness of growth over a whole estate or group of estates is the ideal aimed at, but in tea, as in almost any other form of agriculture, it is found that small units vary greatly in their productive capacity; particularly in these days of restricted crops, planters are very much concerned with improving the weaker areas while maintaining the vigour of the better areas. In this section are set out some impressions which have been gained following estate visits.

Before a weak area can be improved it is essential to know the cause of unthriftiness, and this is usually the most difficult problem. If the area has always been a weak one its low productive capacity may be due to one or more of the following causes:—

- (a) The original planting and planting material used were bad.
- (b) The soil is naturally poor or is not sufficiently acid.
- (c) The land is waterlogged.
- (d) Exposure to strong winds has prevented development of the plants.

Of these causes it is relatively easy to determine (d) and (c). It is rather more difficult to determine (b) since only limited information is available by a soil analysis, and is practically impossible to determine (a).

Bad planting and planting material can only be rectified by replanting. If the soil is naturally poor or under-acid the expense of rectifying this is prohibitive except over small areas, where, for instance, sulphur can be used to rectify the reaction. Waterlogging can be remedied by drainage and wind damage can be rectified by wind breaks which take some years to develop.

In a second group are areas which were at one time high productive units and have since deteriorated. Unthriftiness may have resulted from deterioration of the soil by erosion or bad soil management. If this is the case it is possible to spot the trouble but it is doubtful whether much can be done to improve the areas without great expenditure and no real benefit can be expected by replanting. Or, the plants as a result of age or hard treatment or disease may have been weakened physiologically. This would appear to be one of the chief causes of unthriftiness of tea in S. India. If the condition of the plants is not too bad, vigour can possibly be restored by very much lighter treatment, by manuring and by resting. If there is going to be a response to treatment, it will come fairly soon, but in many cases the best treatment will not do any good—the bushes have been weakened too much—and the only policy which remains is to replant. Although very little has been done by way of replanting in S. India, there are cases where it has been attempted and has proved a great success. This is most encouraging and

serves to show that even very old tea land, provided the land is in good heart, can be made to grow highly productive plants.

The first step in considering improvement methods is to study the areas closely and to study their history. The limiting factor to growth should be sought by a process of elimination of the possible causes of unthriftiness. It may often take time to do this, but it must remain the basis of improvement for, unless the limiting factor is found, expenditure in other directions may well be a waste of money. If, for instance, the soil is under-acid or the plants have been physiologically weakened, no amount of manure or drainage or cultivation can possibly do good.

Green Manures.—Although increasing interest has been shown in green manuring during recent years it is nevertheless clear that many planters have become doubtful of this form of manuring and agricultural practice. A note has therefore been prepared with the purpose of examining the possible reasons why green manuring has not always been the success expected of it, and making some suggestions regarding the treatment of green manure crops. The note covers the majority of points which have been raised in correspondence and discussion.

To those engaged in finding ways and means of preserving and increasing the cropping capacity of agricultural land the use of green manure crops to this end always presents itself as one of the most attractive possibilities. It is not, however, a method which can be adopted successfully without the most considered planning, and this is conclusively illustrated in the innumerable cases of doubtful good, or distinctly harmful, results which have appeared in the long series of trials with many crops and in several countries. Such trials have included cultivation of a green manure crop between two successive produce crops in the case of annuals and growing the green and main crop in association in perennial plantations. In a review of the results in general, the fact emerges abundantly clearly that the agricultural value of green manuring depends on the quantities of nitrate and of other nutrients furnished *at the time the main crop is actively growing* and on the amount of humus-forming material. The essential feature of success in green manuring would therefore appear to be the Time Factor or the establishment of a cultural programme which provides for harmony of growth and elimination of competition between the main crop and the green manure.

There are two classic examples of green manuring which bear out this assertion. The first example is one of failure and illustrates that the Time Factor was wrong. At the Woburn Experiment Station in England two successive green manure crops are grown and ploughed in during the summer. Wheat is sown in autumn immediately after the last ploughing—after the wheat is removed more green crops are grown. The green crops under trial are mustard and tares. For some years the yields of wheat were maintained at a good level, but they got poorer as the experiment proceeded. In spite of the large amount of green manure ploughed in, these plots have actually deteriorated and are no better than the unmanured plots. The appearance of the wheat crops suggested that the poor results were simply due to nitrogen starvation, and in point of fact, treatment with nitrate of soda doubled the yield. The yield after tares—a leguminous crop with more nitrogen—fell more than that after mustard which contains less nitrogen. The explanation of these results is that tares produced more nitrate than the mustard, but did it quicker. The tares therefore gave rise to nitrate during

the winter when most of it would be washed out before the wheat could use it, while from mustard, decomposing slower, some nitrate was left available in spring. There is little doubt of the substantial correctness of this explanation and on this view the system of green manuring has failed because the time element was wrong and the soil had been drained of nitrogen, by both green crops, only more so by the tares.

As against this failure, there is the result on sugar which Clarke obtained at Shahjahanpur. Here is a case of extraordinary success by green manuring, and is one which illustrates the possibilities of green manuring provided the time element is right. The problem which Clarke faced was to find out the condition of cultivation necessary to decompose the green manure he used, *C. juncea*, in such a way that well-aerated soil, containing sufficient organic matter to prevent rapid drying out of the soil, is ready for the sugar crop in March; and the condition such that nitrogen is protected from loss until it is wanted, and is then present in a form which can be rapidly mineralised for the use of the main crop. The method of soil treatment was adjusted to bring about the early stages of decomposition of the green manure in the presence of ample moisture. The rainfall was carefully watched, and irrigation resorted to if it fell below 5 ins. in the first fortnight of September. The moisture, in the early stages of decomposition, ensured the growth of mycelial tissue, so that nearly all the nitrogen came into easily decomposable form. As the soil gradually dries out in the dry weather which follows, nitrification ceases, and the nitrogen is consequently stored until the cane is planted under irrigation in March. The final result was the production of a crop of 30 tons of cane/acre without the addition of any manure apart from the green crop grown on the same land during the previous rains. The practical result was worth Rs. 90 per acre. Along with this treatment estimates of nitrate were made and these showed that the accumulation of nitrate reaches its maximum in May and June just before the heavy rains start. The final yields were in proportion to the mineral nitrogen present in the first period of growth (March, April, May and June) which suggests at once the importance of nitrogen in the early stages of the growth of sugar cane. In this abundantly successful experiment the value of the time element in fitting in the two crops—green manure and main crop—is well illustrated, as also the importance of the time element in so far as it concerns the time at which the main crop most requires its supplies of nutrients.

In the case of tea extensive green manuring will involve growth of the two crops in the same soil, and the question arises—is it possible to hit upon a cultural programme which provides for harmony of growth between tea and any green manure that might be grown in it?

This end cannot be achieved if, by the association of the crops, there results vigorous root competition for the limited supplies of available nutrients *throughout the year*. The evidence for this is to be found in the depressing effect of the green manure crop on yield which is known to occur during the time the green crop is standing.

Secondly, it cannot be achieved if there results vigorous root competition between the crops for the limited supplies of moisture which are ordinarily available during the prolonged dry weather period, characteristic of the climate in S. India. Lest there should be any doubt concerning the importance of moisture competition, two facts may be mentioned. The first is that the shrub type of green manure such as *C. anagyroides* and *Tephrosia* sp. are relatively deep-rooted plants which derive their moisture supplies from approxi-

mately the same soil horizons as tea; the second is that Giary, in Indo-China, has shown that the deep layers of soil upon which deep-rooting plants are not growing contain a higher percentage of moisture than cropped land. On these grounds the deep-rooted leguminous plants will be in highly active competition for moisture with the main crop, and these findings are confirmed by Joachim who showed that bush green manures should not be allowed to continue to grow during periods of drought as the shade they afford does not appear to counteract losses of soil moisture through evaporation.

Thirdly, harmony cannot be achieved if green manure loppings which are coarse and hard and have a high C/N ratio are incorporated in the soil at about the time of intense root activity on the part of the main crop, since by their incorporation and subsequent decomposition the available soil nitrogen becomes temporarily locked up. The full energies of the soil cannot be simultaneously directed to the two processes of supplying nitrogen and decomposing organic matter of C/N ratio much greater than 10 : 1.

Waksman showed that when plant material contains about 1.7 per cent nitrogen there seems to be sufficient nitrogen for the growth of those soil micro-organisms, at first chiefly fungi and later mostly bacteria, which decompose the material more or less completely. When the plant material contains less than 1.7 per cent nitrogen, additional nitrogen will be required before the organic matter is completely decomposed, and such additional nitrogen is obtained from the soil. The total amount of green material produced by green manures of different species varies considerably and generally increases with age (up to 6 months) but as important as total bulk is the ratio, leaves : stem. For *Crotalaria* sp. and *Tephrosia* sp. this ratio was found to be 1 : 1 at 4 months and 1 : 2 when the plants were in flower. Moreover, the nitrogen in the dried matter decreases considerably with age, e.g., *C. anagyroides* contained 3.87 per cent nitrogen at 2 months; 1.69 per cent at 4 months and 1.22 per cent at 6 months. The effect of turning in any but young and succulent plant material about the time of intense root activity is therefore apparent.

On the other hand, the practice of green manuring has every prospect of success if the programme is so arranged that there is minimum root competition for available nutrients at particular periods of intense root activity on the part of tea; if there is no competition for moisture in the dry period; if only the most succulent loppings of low C/N ratio are incorporated in the soil about the time of vigorous root activity on the part of the main crop; and if it can be arranged that loppings store in the soil during the dry weather and release with the early rains the maximum quantity of mineralised nitrogen; also if additional loppings can be used to provide a ground cover or mulch during the dry weather; and finally if the roots of the green manure crop can by absorption immobilise soluble nitrogen at times when it is most liable to be leached out of the soil in the drainage water and thereby store up such nitrogen for the future use of the main crop.

If we knew a lot more about the root activities of tea than we do at present the problem of fitting in the two crops to the best advantage would be a much simpler one than it is. There is, however, a good deal to suggest that it is the habit of tea to develop an active feeding root system at two periods in the year when conditions of moisture and temperature are optimum, and that it is the habit of tea to absorb a large proportion of its annual requirements of plant nutrients at these times. Possibly, too, the final yield is proportional to the amount of nitrogen then available. Within narrow

limits these two periods are April/May when the temperature is high and the spring showers provide ample moisture, and again in September/October when similar conditions prevail. On the assumption that this hypothesis is correct, or nearly correct, one of the chief difficulties of green manuring is overcome. For we now know that at these two periods it is necessary, if harmony is to be achieved, to plan the programme of green manuring in such a way that root competition between the two crops is eliminated or reduced to a minimum. Further we know that it is not good policy to incorporate in the soil about this time any but the most succulent type of loppings. Succulent loppings of low C/N ratio will not interfere with the available nitrogen in the soil. Hard coarse loppings, on the other hand, which require additional nitrogen for their decomposition, will temporarily immobilise part of the available soluble nitrogen. Again we know that during the S. W. monsoon tea roots are not at their most active stage, and that an appreciable proportion of the soluble soil nitrogen is liable to be leached out unless immobilised. Therefore at this time the roots of green manures will not be in a serious competition with the main crop, and such nutrients as they absorb, particularly the nitrogen, may otherwise be a total loss. The degree of leaching which does take place is well illustrated in one of the Peradeniya experiments which estimated the percentage of nitrate and nitrite nitrogen in the soil at fortnightly intervals. In this experiment some plots had been green manured in early December. The maximum percentage was reached 6 weeks after the incorporation of the green manures and remained high until the first monsoon rains when it fell rapidly within 14 days. In the case of plots receiving *C. anagyroides* loppings the amount of nitrate and nitrite nitrogen fell by over 350 per cent in 14 days, and remained comparatively low throughout the monsoon. The control plots, receiving no green manure, also showed maximum nitrate content prior to the heavy rains, and a rapid decrease within 14 days after the start of the rains.

Taking these points into account, the problem which follows is to fit the green manure crop into the scheme of things in such a way as to avoid factors which might lead to unfortunate results and to include only those which give useful results. The only way of doing this is to regard the green manure crop as a comparatively short-lived one and to proceed with a programme on these lines.

The crop is sown in April or early May. This is a time when tea is highly active, but in the seedling stage there is no fear of excessive competition for nutrients.

It continues to grow throughout the S. W. monsoon, and fill the highly important role, along with weeds, of immobilising a portion of the excess soluble nitrogen which might otherwise be leached out. This nitrogen is being stored in the green manure for use by the tea later on.

About late August the green manure will have grown sufficiently large to be ready for lopping. It is accordingly lopped and either left on the soil surface to decompose or is incorporated in the soil, perhaps along with the artificial manure mixture. The loppings, being tender, decompose readily under the prevailing climatic conditions and release plant food. Or decomposition might proceed to end of the first stage, cease during the dry weather, and finish with the early rains in the spring. The extra humus helps to check further leaching out of the soluble nitrogen at this time.

The second period of intense root activity of the tea takes place during September and October (approximately), and in the same way as root

activity of pruned tea is considerably lessened, we may expect that the root systems of lopped green manures will be comparatively inactive, and therefore there is least possible competition between the two crops during the months of September and October.

By the end of December the green manure crop will, under favourable conditions, have put on a fair amount of growth, and now is the time to dig it up. By doing so competition for moisture during the coming dry weather is eliminated, and the green manure crop, laid on the ground, forms a protective soil mulch which keeps the soil surface cooler and slows down the rate of evaporation of moisture from the soil. In a long drought this mulch will be of immense value. It has been established that loppings of shade trees and green manures laid as mulch on the soil surface at the beginning of the dry weather exercise a very favourable effect on the soil moisture content. Gradually the mulch decomposes and releases for the tea such nutrients as it has absorbed.

This would seem to be the sort of programme which will give all the benefits of green manuring and avoid all the disadvantages, for it eliminates competition for nutrients and moisture at vital periods and allows of fulfilment of the most desirable functions of green manuring. The practice of green manuring is fairly widespread in tea plantations in S. India, and on the whole has given rather disappointing results. This article has contrived to show why the results have been disappointing, and how much better results might possibly be obtained by establishing more precise harmony between the two crops to be grown in association.

No experiments have been conducted in S. India, so far, which could support the proposals for a green manuring programme which are made here, but it is rather interesting to note that results obtained by growing *Boga medeloa* in tea for two years in N. E. India show that there is a falling off in yield of tea during the time green manures are growing but there is a substantial increase in yield following the digging up of the green manure and its subsequent decomposition. This would suggest that the root competition which has been referred to is of real moment, and appears to establish the fact that, provided competition for nutrients (and in S. India, moisture) can be reduced to a minimum, there are great gains to be had by green manuring. The time element is the vital factor—success or failure of green manuring will depend on the use of green manures at the right time—and this is perhaps even more important under the particular climatic conditions prevailing in S. India than in any other tea-growing country.

The obvious procedure is to sow the green manures in fields in the first year from pruning. A small part of the green manure crop can be left to grow for seed.

The success of the programme which has been mentioned above is dependent on the soil being good enough, and the climate sufficiently mild, to enable the usual shrub type of green crop to produce an appreciable amount of growth in the period May–August. Under soil and climatic conditions of some parts of S. India worth-while growth may not occur during this time. In this case there appears little prospect of being able to use green crops with any degree of success, and the soft weed growth which is allowed on most estates will have to perform some of the functions of the legumes. A modification is, however, possible under the more extreme conditions where growth is very slow. This would allow sowing the green crop in November and

leaving it to grow till the following August. As the plants will be small in the April/May period they should not interfere unduly with the tea at this time.

Bearing in mind the immense possibility of green manuring as a means of maintaining and increasing the fertility of the soil the writer commends the conception of the practice here mentioned as worthy of extensive trial.

THE SOIL EROSION PROBLEM ON TEA ESTATES

General.—The writer has endeavoured in the course of tours in the tea districts of South India to gain an impression of the extent to which soil erosion is taking place on tea estates. To appreciate the position fully it would, of course, be necessary to make careful observations in each district throughout the year, and give the matter very particular attention. It may, however, be of some value to set down such estimations as have been made.

It can be said at once, and with confidence, that the very large majority of planters are fully aware that the type of land, almost entirely mountain-side and hill-side land, with which they have to deal is readily subject to erosion of the most insidious type, and which is capable of rendering the properties, which are their charges, uneconomic productive units, not in the course of decades, but in the course of a very few years. Everything—the climate; the type of agriculture; the configuration of the land; and the soil types—all these make it essential that preventive measures against soil erosion should be taken from the first opening and maintained and improved.

There are some estates in South India which as a result of faulty methods in the past have already been partially ruined by soil erosion, and many others have suffered very severely. Taken all over, however, the position is bad, though more attention is required. Soil erosion, unless it is proceeding vigorously, is not easy to detect, and it is therefore the slow but continual rate at which it proceeds, which makes it so insidious a problem. It would certainly be a mistake of the first magnitude to imagine that the average estate is free from erosion. The plain truth is that it is not, and the writer strongly recommends an intensification of preventive measures at present in operation; in some cases an improvement in these measures; and in other cases a revision of policy in regard to erosion.

As is made clear in the text of the notes which follow, the best method above all others is the provision of a ground cover. This is the method which is doing more than anything else to save South Indian estates at the present day and in its most intensive form it is the result of the abandonment of clean weeding throughout the year where it had, in the past, been the practice.

A second influence for good has been the abandonment of the use of certain tools—the scraper, etc.—which are so conducive to erosion.

Terracing is not a particularly common anti-erosion method in South India, principally because stone is not easily and cheaply available in many of the districts, though let it be said that there are some magnificent examples of terracing. It is a method which might be given more consideration in districts where material is plentiful. The use of grass sods for terracing is a method which is deserving of consideration.

Drainage is a very much more widely used method, and comes second to ground covers (with which are included shade and litter).

It is in the direction of drainage that the writer believes the chief improvements can be made. The construction of drains is not, everywhere, of the most suitable design, and it is strongly felt that advantage would accrue if the most modern designs of anti-erosion drains were fully studied. The ordinary straight drains, so often seen, could with much advantage be altered to conform with modern designs. The construction of reinforced bunds on the lower sides of the drains is an uncommon feature in South India, but is a work worthy of earnest consideration.

The Lock-and-Spill, and Reverse Slope, drain designs reinforced by a bund on the lower side are the construction types which are eminently suitable for most districts, and it is considered that greater use could be made of these measures. The use of hedges of green manures, and sometimes of grass-planted strips, appears to be widely recognised as a useful anti-erosion measure. Continuance in the use of this means is recommended.

Attention has been drawn in the main text to the influence of shade trees and litter (which includes all vegetable matter), as an anti-erosion measure. A majority of the estates in S. India are comparatively well shaded, and it is recognised that pains are taken to supply to the tea areas, in one way or another, as much vegetable litter as possible. If the advantage of so doing has been looked upon as being chiefly from the manurial point of view, it is hoped that more point will be given to the value of the practice of adding litter, particularly as the manurial value is subsidiary to the important influence of shade trees and litter as an anti-erosion measure.

Perhaps one of the most noteworthy features in S. India is the care which is taken to plant up roadside and ravine edges and in fact all bare spaces, with creeping plants such as *Indigofera endecaphylla* and the 'Nilgiris daisy'. This work is obviously of great importance, and nearly everywhere the steps taken in this direction are adequate.

As anti-erosion measures, silt pits and trenches placed on the contour are not usually seen. By themselves these measures are insufficient, but they are useful methods for a crop such as tea, and if backed up by the provision of a ground cover, they are particularly useful. As the provision of a ground cover—usually in the shade of a light cover of weeds—is so marked a feature of our tea estates, it may not be out of place to draw attention to the possibilities of these measures.

Finally, the following thoughts may be set down.

(1) It is very improbable that any one estate in S. India is completely free from erosion. Because erosion is not easily detected, there is no certainty that it is not proceeding; it is very likely true to say that erosion is proceeding at a rate which is unsuspected.

(2) In the case of land of any slope at all, at least two of the many measures of preventing erosion should be put in hand. For S. India ground cover is the main and most suitable measure, but this should be supported either by drains, or terraces, or silt pits, or silt trenches.

(3) It is well worth emphasising that if erosion is going on even on a small scale, it involves the continual removal not only of plant foods but of organic matter and humus. The prevention of erosion is therefore the equivalent of adding a good dressing of manure, for even with a relatively low rate of erosion, more nitrogen, phosphoric acid and potash are lost than are

contained in a usual manurial mixture. Moreover, if manures are added while erosion proceeds part of their value is lost by erosion. And not only is plant food lost but soil structure is adversely affected.

(4) The maximum amount of erosion occurs when heavy plumps of rain follow a long dry spell and ground covers have died back.

(5) Throughout the notes which follow it will be noticed that stress has been laid on the importance of developing more than one precautionary measure.

In the following paragraphs will be found a discussion giving further details relating to the soil erosion and land conservation works.

PART I—CONDITIONS LEADING TO EROSION

Before a discussion of details it will be convenient to consider the several reasons why tea land in S. India is subject to erosion. These are grouped under the following heads :—

(a) **Topography.**—The greater part of the land under tea in S. India, or which could be brought into tea cultivation, is situate on the hill sides and mountain slopes of the range which runs along the west coast. The degree of slope varies considerably, but practically nowhere is the gradient small enough to make erosion on account of slope an unimportant factor; more usually it is great enough to make it one of the most important factors. The slope of land naturally influences the rate and amount of surface run-off water which increase with the first increments of slope (up to about 4°), and then tend to approach a constant value. With slope and rate of water-run-off is associated actual soil movement or erosion which is found to be moderate in extent below 4° gradient, but the steeper slopes produce a very rapid increase. It will be recognised then, that on account of its topography, tea land in S. India is immediately exposed to erosion.

(b) **Climate.**—The second factor which leads to erosion is climate. Most of the tea districts are in the area which receives both the S.W. and N.E. monsoons, so that the total average rainfall, while it varies considerably from place to place, is seldom below 50" and may be as high as 300". This in itself represents a vast amount of water falling on the land, but more important than total rainfall are the distribution and the liability to torrential downpours spread over a few hours. Both these latter are factors which influence erosion a great deal, for our tea land receives a large percentage of its total rainfall in the course of 6 or 7 months of the year, and nearly everywhere very heavy falls of rain are liable to occur in the space of a few hours. The problem then arises of constructing conservation works whose capacity is capable of dealing not only with a high total rainfall but an unevenly distributed rainfall including plumps of up to 6 inches which may fall in a single day.

(c) **Soil Type.**—It is well established that soil type is an important factor in erosion. Some soils are highly absorptive of rain water, and have a high rate of percolation and rapid underground drainage which increases their resistance to wash. Others absorb water slowly and have a slow rate of percolation. Both these types of soil are to be found in S. India, and though it is fortunate that the highly absorbent types are more common than the others, yet even the best of the former group are subject to erosion on account of the type and structural make-up.

These are the three main factors which predispose S. Indian tea land to erosion by surface wash, and by gullyng, as soon as it is cleared for cultivation. In the natural state the ground cover of vegetation (jungle or grassland) appears to be more than sufficient to reduce possibilities of erosion to negligible proportions. Wind, which is so conducive of erosion in other regions, is a factor with which we seldom have to reckon.

Clearing the ground of its natural vegetation for purposes of cultivation immediately exposes the land to erosion through the influence of other factors ; among these are :—

(1) The destruction of the natural vegetative barrier to erosion.

(2) The disturbance of the soil which makes it further liable to movement.

(3) The exposure of the land to the beating and churning effect of heavy rain, and to the unfavourable action of strong sun.

Thus, there are two groups of factors conducive of erosion—the first of which includes topography, climate and soil type, and the second of which includes those factors which come into operation at the first opening.

Following on these comes a third group which arises from the system of agriculture adopted. This group includes :—

(1) The nature, depth and direction of cultivation practices, since erosion is either aggravated or reduced according to whether these are best or least suited to the particular conditions.

(2) The type of crop grown. Tea, being a moderately closely spaced permanent crop, falls between the two groups of plants, viz., closely spaced perennials and widely spaced perennials, which are the groups which expose land least to erosion and which make for the most severe erosion respectively.

(3) The agricultural system adopted, especially as it relates to crop species. Here again we find two extremes—either the main crop is the sole occupant of the land in which case erosion is most liable to occur, or along with it are grown shade trees, cover crops and weeds, in which case erosion is least liable to occur.

PART II—LOSSES WHICH SOIL EROSION MAY CAUSE

Having discussed reasons why our tea land is so subject to erosion, the natural sequence is to consider what losses occur when erosion takes place. These losses are dealt with under several headings.

(1) Loss of Soil

This is the most obvious loss when erosion is proceeding apace, and is of course, particularly striking in the case of gullyng. Erosion may, however, be going on at a harmful rate without the loss of soil being noticeable to the eye, and in this degree it assumes its most insidious character, for it is only after an interval of years when rocks and stones appear on the surface, the rooting system becomes exposed, and the sub-soil is laid bare that the losses which have occurred are fully appreciated. And by the time that

has happened it is too late to think of conservation or reclamation measures. This loss of soil is one which means nothing less than a reduction of growing space.

(2) LOSS OF NUTRIENTS

The second loss which occurs is of nutrients. Among these are included the majority of plant foods required by Tea.

(a) **Nitrogen.**—Nitrogen is lost chiefly in the form of organic matter (insoluble nitrogen). Less is lost in the soluble nitrate form since the first rains displace the soil solution and drive it deeper into the soil so that the surface run-off does not come into contact with the normal soil solution. Indirectly nitrate is lost by leaching, and these losses are presumably heavy.

No figures of nitrogen losses by erosion are available for S. Indian tea land, but it is of interest that Duby and Miller at Mussoori found that 98.88 lbs. nitrogen were lost per acre over a two year period in cultivated land, and the figure was very slightly less in uncultivated land.

(b) **Phosphorus.**—This is a second essential nutrient which is lost by erosion. In the same experiment Duby and Miller found the loss of phosphorus to be 47.47 lbs. over the same period. Unlike nitrogen, losses of phosphates by leaching hardly occur at all since even the most soluble types of phosphate which might be added to the soil rapidly become 'fixed'.

(c) **Potassium.**—Potash salts, the third usual ingredient in a manurial mixture, are also lost. Duby found that losses of potassium were small but even then were considerably greater than the amount which would be added in an ordinary commercial fertiliser. As with phosphorus, losses of potash by leaching are negligible.

Sulphur, Calcium. These also occur in run-off water.

It will be fully appreciated that if erosion is proceeding, even at a moderate pace, it is capable of removing each year more than sufficient nutrients to raise a good crop of farm produce, and thus not only is prevention of erosion equivalent to a substantial dressing of manures, but that unless it is prevented a large proportion of manure added in any one year is liable to be lost.

(3) LOSS OF ORGANIC MATTER, INCLUDING HUMUS

Losses of organic matter through run-off water are considerable. Much tea land is already deficient in organic matter, and unless the supply is continually being replenished, it will continue to diminish chiefly because the climate is such that oxidation of organic matter proceeds at a high rate, and cultivation increases this rate. Loss of organic matter is closely associated with loss of nitrogen.

(4) LOSS OF TILTH

This is essentially a structural loss. The value of good soil tilth is too well known to need description here. Suffice then to mention that one effect of erosion is to destroy the aggregate of particles of various sizes which is

so noticeable a feature of land in good tilth. The destruction of tilth may occur in other ways besides erosion, such for example as cultivation in unseasonal times; but erosion is inimical of tilth both on account of movement of soil particles and as a result of loss of humus which provides part of the necessary cementing material.

(5) WATER HOLDING CAPACITY

The breakdown in tilth and the loss of organic matter which have been mentioned as losses due to erosion, have a very important influence on the water holding capacity (and ability to absorb water) of a soil. In areas which are subject to long droughts the effects of a decrease in these soil properties are of utmost importance. They may, without doubt, be included among the vital losses which erosion leads to.

(6) SOIL MICROFLORA

The activity of soil microflora of beneficial types is so closely bound up with fertility, that anything which reduces their numbers has a direct influence on the processes of digestion and chemical activity in the soil. Prevention of erosion, it is well known, is an important factor, both in itself and in its results, in keeping up the microfloral population of the soil. It is common to talk of a soil with a high population of beneficial organisms as 'alive', and of soil deficient in microfloral growth as 'dead'. The description is a good one.

(7) LOSS OF RESISTANCE TO DISEASE

To the losses above mentioned might be added a seventh—the loss of resistance to disease. It has been estimated that 10 per cent of the world's total production of agricultural products is lost as a result of disease, and it is further established that a large proportion of this 10 per cent loss is the result of disease brought about by unsatisfactory environmental conditions. Crops grown under conditions of high soil fertility, and all that it involves, are very much less subject to pests and diseases than crops grown in poor and eroded soils. Pests and diseases of highly parasitic type will, of course, occur in the best regulated circles, and on crops grown on the most fertile soils. But when fertility is reduced, as it is by erosion, predisposition to disease is accentuated, and the cost of control is increased. It is therefore not out of place to include loss of resistance to disease as a direct loss which occurs through erosion, and it is no exaggeration to say that this assertion has many examples in S. India to bear it out.

(8) LOSS OF QUALITY

A discussion on the results of erosion would not be complete without mention of quality. The value of quality in agricultural produce is becoming more and more appreciated as education advances and as world communications are speeded up. Overproduction of commodities also tends to put a premium on quality—clearly reflected in the last slump.

Separately and collectively these losses produce a reduction in soil fertility—which in turn means nothing short of reduction in crop. Thus it is that, as erosion proceeds and all the results follow in its wake, smaller and smaller crop is produced at greater and greater expense. Eventually a point is reached where the cost of production exceeds the value of the product.

PART III—SOIL CONSERVATION METHODS

GROUND COVERS

It has been established beyond all doubt, and is agreed by all authorities, in all quarters, that the establishment of a ground cover is the best means of preventing soil erosion. It is the surest solution to the problem of soil conservation and it is certainly the measure which is doing more than anything else to hold up the soil and maintain the fertility and capital value of tea land in S. India. That its value is recognised here is reflected in the almost complete abandonment of clean weeding which in turn is, very probably, the reason why a large number of tea estates in S. India are producing sufficient crop without resort to artificial manures.

In the fullest sense ground covers include shade trees; tea crop itself; erect green manures; all cover crops, leguminous and non-leguminous whether especially planted or self-sown; and weeds.

As this paper deals with soil erosion, the pros and cons, the advantages and disadvantages of allowing the soil to be occupied by anything but the main crop do not form part of the subject matter except in so far as they relate to erosion. The special influence of shade trees as a preventive measure and the influence of main crop itself are dealt with under separate heads.

The ideal type of ground cover for a plantation crop such as tea would be a low growing leguminous plant; one which is shallow rooted; not a gross feeder; and does not make undue demands on soil moisture; which is, moreover, easily established and long lasting. Although the search continues, no such plant has yet been found, and the best compromise has been to make use of such plants whose characters closely approach the ideal. Thus, the use of a large number of the weeds occurring naturally in a particular district has been invoked, and until the ideal low cover is found, this compromise is the one of which the best use must be made. Certain naturally occurring plants—especially grasses—are, of course, abnoxious and must be removed at all costs. Climbing and deep-rooted plants should also be classified as pests. Controlled weed growth, and all that it involves, or selective weeding, represents then the main defence line against erosion. It is well to remember that an adequately controlled cover of 'weeds' can be just as efficient a preventive of erosion as the rank growth which the estate agriculturist fears and which, once established, is so costly to clear. The objection, frequently expressed, that ground covers interfere with the main crop by removing manurial ingredients is more than off-set by the advantages, since besides the soil conservative effect, there is always the return of such nutrients on decay of the covers. The covers, moreover, immobilise nutrients which otherwise are subject to loss by leaching. It is regarded as being infinitely more profitable to spend extra money on controlled weed growth than on purchasing expensive artificials. Consider, also, the effect of clean weeding all through the year. By it the surface soil is loosened, and to a degree which is sufficient to hasten the washing out of the final soil particles without much improving porosity. The surface water soon meets an impenetrable layer and takes in its stride the loosened surface soil.

How does this defence line work? In a number of ways:—

(a) the effect of a ground cover is to protect the soil from the beating and churning effect of rain whose rate of fall it retards.

(b) It affords protection from the baking effect of sun.

(c) The ground cover provides a mechanical hindrance to the movement of water and soil over the surface and gives the water more time to soak in. The hindrance to movement provided by a low cover is superior to that provided by a high cover (shade trees).

(d) By their rooting systems ground covers tend to keep the soil open and porous and to improve the rate of percolation. The fine root system of low covers induces improved porosity as compared with high covers (shade trees).

(e) Acting as litter the covers enhance the natural capacity for percolation which is reduced in a bare soil where the small particles are washed down and form a filter below surface level. The influence of covers in this direction is more potent than organic matter (see influence of litter).

(f) On their death or destruction the covers provide a supply of litter and then humus and the consequent increase in capacity of absorption.

(g) Ground covers offer the best distribution of organic matter.

(h) Ground covers increase the efficiency and strength of drains and terraces and are particularly important for protecting main drainage lines, natural or artificial, and all open areas.

But ground covers cannot by themselves stop all erosion and must be supplemented by additional and secondary measures of defence—drains, terraces, etc. The secondary defence measures are of particular importance following a period of drought when most of the cover will have died back and heavy plumps of rain fall. It is common experience that heavy plumps of rain following on a long dry period lead to intense erosion.

Man-made erosion is due to interference with the natural vegetative cover. Natural forest and grass-land under any condition of soil or climate are almost one hundred per cent free from erosion.

Influence of the Tea Crop on Erosion.—It has often been said that the best cover for tea is—tea. There is a large measure of truth in this statement, but it is quite wrong to assume that even a complete cover of tea is an adequate means of preventing soil erosion. It helps, of course, by having the same influence as other covers, but it must be remembered that tea is a comparatively widely spaced crop, and only for relatively short periods is there a complete cover, even in the fullest fields.

Some interesting experiments have been conducted to test the influence of ground covers :—

Experiment in East Africa.—Plots were on a uniform slope of 1 in 6. Over a period of 4 months, with a rainfall of 56", clean weeded plots lost a maximum of 18 tons/acre; cover crop plots lost a maximum of 1/6 ton i.e., cover crop reduced erosion more than one hundred-fold.

Experiment in America. (see Tech. Comm. No. 5, Soil Erosion, Dec. 1929). In this case eroded and non-eroded soils were analysed.

	<i>Eroded</i>	<i>Non-eroded</i>
Water holding capacity ...	46·8%	67·2%
Nitrogen ...	·16%	·49%
Humus ...	6·60%	14·60%
Dry weight of wheat produced...	5·5 lbs.	12·1 lbs.
Water equivalent per pound dry weight produced ...	472	343

Vegetable Mulch.—The practice of carrying vegetable material into tea land, from outside, and spreading it on the soil surface, has long been recognised as having a manurial value, and as being a means of stopping evaporation of moisture from the surface soil. Apart from these influences it is a practice which is particularly valuable as an anti-erosion measure. Not only does the mulch offer mechanical hindrance to the movement of surface run-off water and the soil movement, but vegetable matter, as already mentioned, is highly absorptive of moisture and has a beneficial influence on the rate of percolation. Moreover, it adds to the humus content of the soil.

There is immense scope for the use of this method in S. India where many estates have an abundance of waste land and jungle from which such material can be collected.

Such vegetable matter is best applied if laid in strips owing to the danger of fire in the dry weather.

Shade Trees.—Shade trees have a distinct value in preventing soil erosion. Their influence, chiefly indirect, is on several accounts.

(a) By the branches and leaves, together with the litter accumulated, they shade bare soil (from the sun), and prevent the unfavourable baking and cracking effect.

(b) They break and reduce the rate of fall of heavy rain, and lessen its beating and churning effect on the soil.

(c) They render the soil more porous and absorptive by the ramification of their rooting systems. Also the roots act as channels along which the water drains downwards.

(d) They shed litter which absorbs water and influences percolation beneficially.

These factors make the presence of a cover of shade of appreciable importance in the problem of erosion as a whole, and to their other benefits this influence must be added.

The mulch of *Grevilleas* is particularly useful in this direction, as it is slow to break down and undecomposed litter has better influence on soil erosion than decomposed litter.

Hedges.—Hedges may be :—hedges of the main crop ; hedges of erect-growing green manures, leguminous or non-leguminous ; hedges of low-growing plants, other than grasses ; and grass hedges. The establishment of permanent or semi-permanent hedges is usually easily accomplished, and is not expensive ; nor is much upkeep required. As a conservative measure hedges are of maximum value if planted along contour lines, or in strips along the contour, but unless supplemented by other precautions, not too much reliance should be placed on them. As they are not likely to be used as a main defence against erosion, they have a particular value for tea estates. A careful watch should be maintained to see that no small gaps occur lest run-off water be diverted to these gaps, for this would tend to gully. The species used should accordingly be closely planted.

A degree of gullying may also take place if single lines of erect green manures are planted up and down the face of slopes. It is infinitely

preferable to plant such rows or hedges in lines approaching the contour, or in staggered clumps.

Leguminous plants suitable for hedges.

Crotalaria anagyroides.

„ *striata*.

„ *junca*.

„ *usaramoensis*.

Cajanus cajan.

Clitoria cajanifolia.

Tephrosia sp.

Non-leguminous plants suitable for hedges.

Tithonia diversifolia—Sunflower.

—Mugwort.

Grasses suitable for hedges.

Guinea grass (*Panicum maximum* or *P. jumentorum*).

Napier grass (*Pennisetum purpureum*).

Paspalum (*Paspalum dilatatum*).

Maveel grass (*Andropogon annulatus*).

Vacancies and bare spaces.—An essential precautionary measure in land conservation on tea estates should be to maintain all vacant areas, in and about the tea land, under a cover of vegetative growth. A variety of plants may be used for this purpose, and with a view to increasing fertility, the leguminous species (see suitable plants for hedges) are to be preferred, but sunflower and mugwort are particularly suitable non-leguminous plants which may be used. In view of the fact that the seed of many commonly used leguminous plants is extremely liable to disease when the plants are thickly grown over wide areas, it may be useful to allow seeding to take place in small areas of this description and to collect the seed.

Litter as an anti-erosion measure.—The litter which is added to the soil in the form of loppings and leaf fall from shade trees, loppings from green-manures, prunings, dead weeds and any vegetable material which is carried on to the land from outside has a profound influence in the prevention of erosion. The influence of litter is in several directions:—

(1) It has been assessed that the water holding capacity of litter is about 8 times that of soil.

(2) Litter fulfils the function of preventing the silting up of the soil pore space caused by washing down of the finer fractions.

The percolation rate of water is thus preserved by the litter. It has also been shown that percolation of mineral forest soil below undecomposed litter was superior to that of bare land. Thus it is to be inferred that vegetable remains that have not completely decomposed are of greatest importance in preventing the silting up of the surface layer of the soil, and thereby of preventing soil erosion.

It is then beyond question that the practice of adding litter to the soil by whatever means is a good one. It also has a decided manurial value and an influence on tilth. Where there is danger of fire the litter carried on should be laid in strips. This litter influence on erosion is, incidentally, a fairly substantial argument against the necessity of incorporating all vegetable

matter in the soil. Percolation should not be confused with absorption which is the capacity of a soil for holding water in its pore spaces.

DRAINAGE WORKS

The more familiar conception of drains is that they should act as channels for the rapid disposal of excess water along convenient lines. This conception, in the light of modern soil conservation methods and agricultural practice, has been considerably modified, and surface drains are now looked upon as having the following functions:—

(a) As being a means of ensuring the maximum absorption of rain water falling on the land by reducing the rate and quantity of surface run-off;

(b) As being a means of controlled removal of surplus water—the amount which the land cannot absorb;

(c) As being a trap for the collection of spoil which settles in them, the drains being so constructed as to act most efficiently in this direction. The collected spoil is returned to the land, later.

The basis of design of modern drainage systems is such that the drains meet most effectively the above requirements, and properly-constructed drains have been proved to be highly successful in soil conservation. For the particular conditions of topography and climate under which tea is grown in S. India, there is little question that drainage represents the most important defence against erosion, being second only to ground covers, except in the case of very stony or rocky areas. Not only has attention been directed to design, but equally important is the question of siting drains. The ideal placing of drains is along contour lines, the distance between the lines being dependent on such factors as gradient, soil type, and rainfall distribution. In the case of permanent crops already established and planted in lines, not along the contour, it will be found extremely difficult, without removing a number of the growing plants, to place drains along contour lines. While some authorities insist that the benefits to be derived by having the drains so placed are such that it is worth while to remove those plants which interfere with the lining, it is more than doubtful whether this applies to tea where drainage is not likely to be the only work of conservation but is probably supplemented by other measures. Moreover, even in the case of replanted tea or new clearings, while there is everything to be said for following contour lines for drainage works which will be done before the planting of the crop, it does not necessarily follow that the crop should be planted on contour, for while contour planting may be perfectly convenient in the case of widely-spaced permanent crops, there are obvious disadvantages in the case of a closely-spaced crop such as tea, for this type of planting would present difficulties in cultivation, manuring and other practices. The few trials which have been given to contour planting tea in S. India appear for some reason or other to have given disappointing results.

Consequently, while the siting of surface drains for existing tea areas will usually follow lines which have no relation to the contour, yet there are important points to be considered. The chief of these are that the drain must be placed so that it eventually meets a main drainage line, and secondly, the drain should follow along a line of as even slope as possible and should never be steep at any point. Drains following a gradual slope will be more efficient than steeper drains, and a drop of 1' in 25' should approximate to the maximum degree of slope.

The improvement in drain design has been chiefly in the shape of providing drains with obstacles to water flow, and out of this at least two drain types of outstanding value have been developed. The types referred to are the Lock-and-Spill Drain and the Reverse Slope Drain. It is now proposed to give a short description of these types.

Lock-and-Spill Drain Type.—In this type, the drain is so cut to include blocks at regular intervals. The blocks are usually not more than 3' long at bottom and 5' long at the top, and are placed 15'–25' apart in the drains. The height of the blocks, which have sloping ends, is at least 3" below the level of the side of the drain. Water accumulates in the drain between the blocks, and being held there, the silt and soil particles are deposited on the floor of the drain. Meanwhile some of the water percolates into the soil. Eventually the section of the drain fills up, and the excess water flows gently over the block into the next section which in turn fills before the water flows over the following block. In this way the main functions of a modern surface drainage system are fulfilled. The blocks decrease the rate of flow of water in the drains; more time is given for the drainage water to be absorbed by the soil; and the soil particles carried off by the drainage water are given time to settle on the floor of the drain. Other points in construction of drains of this type should be followed:—

The drains should be as wide as possible, but shallow, and with sloping sides. This makes for the best provision of controlled disposal of the greatest amount of water per foot of depth. The wide surface and sloping sides have further advantages among which are included, reduction in cost of excavation; reduction in depth of contained water; reduction to a minimum of drain-side erosion; increase in capacity; provision of large surface for evaporation and encouragement for growth of vegetation. The dimensions recommended for annual or widely spaced crops are:—

3½ ft. wide at the top,

1½ ft. wide at the bottom,

1½ ft. deep.

For tea, however, the dimensions mentioned are probably unsuitable, and a more convenient measurement would be:—

16"–27" wide at the top,

12"–15" wide at the bottom,

and 15" deep.

The blocks left in the drain should be 7"–9" high to provide a gentle spill from one block to the next section of the drain.

The sloping sides of the blocks provide for a slow and easy water flow.

The conversion of ordinary straight drains into a drain of this type is easily accomplished, and will add enormously to the efficiency of the drainage system as a soil conservation measure. The efficiency of the drains will be further increased if they are vegetated and if the locks between the spills or blocks are kept partially full of dead vegetable matter such as cut grass or weeds.

Adjustment of Drain Capacity.—The drainage should be so adjusted that the drains are capable of dealing with the heaviest storms which may be expected. The capacity of the drainage system can be adjusted in the following ways :—

- (a) By regulating the depth,
- (b) By regulating the number,
- (c) By regulating the size of blocks in the drains so as to provide for the holding up of as much water as is desirable.

Disposal of Surplus Water.—Surplus water from surface drains should be discharged slowly over spill blocks into natural or artificial main drains.

Reverse Slope Drain Type.—The principle involved is to cut new drains, or convert existing drains into a series of terraces each with a reverse slope. The terraces break the continuous flow of water and allow the spoil to settle.

The design is improved further by provision of pits at the deep end of the terraces. A stone cushion at the bottom of the spill over the top of one terrace to the low end of the next lessens erosive effect on the drain.

A recommended length for each terrace is 12'–15'.

A recommended average depth of drain is 12"–15".

The conversion of ordinary straight drains into the reverse slope type is a comparatively simple matter, and in view of the large number of straight drains at present to be seen, the reverse slope design is worthy of special note. Reverse slope drains, well constructed, afford the same facilities for water absorption, flow control and spoil trapping as Lock-and-Spill drains, and there does not appear to be much to choose between the two types, both of which are eminently suitable for hill cultivation.

Drains with Pits.—The efficiency of ordinary straight drains can be improved by cutting pits in them every few yards. This would allow for a certain degree of flow-control and deposition of spoil, but it hardly compares in efficiency with the lock-and-spill or reverse slope drain, for as soon as the pits are full of water or spoil the flow runs straight over them.

Disposal of Spoil.—Spoil collected in the locks should be thrown back evenly on the land on the upper side of the drain; or, it may be used to form a low contour bund on the upper side of the drain. In this way the land is gradually terraced.

Reinforcement of Drainage Works.—Although some factors relating to reinforcement of drainage works have already been mentioned, e.g., encouragement of vegetation, there are other means by which drains of the type mentioned can be strengthened while at the same time increasing their capacity. These means are considered to be of special importance in view of the torrential downpours of rain which are liable to occur from time to time to tax the capacity of the drainage system, and which are likely to cause damage to the drains unless they are reinforced.

The main step in this direction is the reinforcement of the drains with bunds, which are low walls of earth or grass sod. There is some dispute as to whether these bunds should be placed along the lower or upper side

of drains. In the first instance, the bunds can be constructed from the earth excavated in digging the drains. If this is used to form a low earth wall on the upper side of the drain it has the particular advantage in that all surface run-off water between the bund and the next drain above must seep through the bund before it enters the drain. The influence of this is two-fold—deposition of silt before the water arrives in the drain, and a reduction of the rate at which run-off water enters the drain. If, on the other hand, the earth-work is constructed along the lower side of the drain, the influence is chiefly in the direction of increasing the capacity of the drain and preventing over-flow during the heaviest downpours. Either way the bunds are a most valuable addition to the effectiveness of drains, and a suggested plan is that in those districts where very heavy downpours occur and the drainage system is liable to be taxed to the capacity at frequent intervals, the bunds should be constructed along the lower side of the drain. Where rainfall distribution is more even, greater benefit is likely to be derived by siting the bunds along the upper side. The disposal of spoil collected in the drains may well be utilised to repair and strengthen the bunds whether they are on the lower or upper side. Further strengthening of the bunds can be achieved by covering them with vegetative growth. If material is available, the bunds can also be strengthened by revetting the lower side to form a low retaining wall of the same height as the bund. Such walls should be constructed to incline in the same direction as the slope of the hillside.

TERRACING

General.—Terracing in any one of its several forms is an effective measure which can be taken to arrest a proportion of the downward movement of soil on slopes. But it cannot be regarded as a complete measure in itself, and should be supplemented by other means. Unless it is supplemented actual harm may be done by run-off water spilling over the tops of terraces. The first principle in terracing is that efficiency depends on frequency, rather than height, and 18 inches height is sufficient for normal purposes.

Material for Terracing.—Several materials could conceivably be used for terracing ; most commonly used materials are :—

- (1) stones,
- (2) bricks,
- (3) grass sods,

depending on which is easily and cheaply available.

CONTOUR STONE EMBANKMENTS OR TERRACES

Special use.—Contour terraces are of particular value where there is a plentiful supply of stone, and where the excavation of contour drains is difficult owing to the presence of rock or other obstacles.

Spacing.—Being less efficient than drains with bunds, stone terraces should be somewhat closer according to the slope of land.

Construction—Essential Features.—In construction of stone terraces the following are essential features :—

- (1) The terraces should have a wide base, and a narrower top,

(2) The lower face should be built with a good slope towards the hill-side. The more pronounced the slope of the land, the greater the lower face slope.

(3) The upper sides should be in a perfect contour line.

(4) It is highly important that the base stones be correctly laid; they must (a) be laid evenly and close together; (b) be laid with a reverse slope to the slope of the land—not level.

(5) Stones forming the edge of the base lowest down the slope should be laid in beds cut for them on a slope into the hill-side.

(6) Stones forming the middle and upper side of the base should be laid in deeper beds excavated for them in a similar way. Thus reverse slope of the base is maintained throughout, and the terrace consequently has a correct slope and maximum stability of structure.

Reinforcement and Protection of Stone Terraces.—It is necessary for reinforcement that the upper sides of stone terraces be protected. This may be done by:

Grassing. The upper side being protected by a thick and closely-planted belt of suitable grass (e.g., Napier, *Paspalum*) or similar vegetation (e.g., *Indigofera endecaphylla*). The effect of the vegetation is to consolidate the terrace and to collect and hold up soil brought down in run-off.

Brick Terraces and Grass Sod Terraces.—These should be constructed on similar principles, and again be afforded protection by a strip of vegetation grown on upper side.

The obstruction which terraces offer to large scale mechanical cultivation operations is no objection to their adoption for tea in South India where practically all operations are done by hand tools.

TRENCHES

General.—The value of trenches as a main anti-erosion measure is limited to:—

(a) Areas with a comparatively low and evenly-distributed rainfall where the trenches can retain and absorb all the water falling.

(b) Land of gentle slope.

They are, however, suitable for steeper land if reinforced by establishment of a suitable ground cover.

Trenches may have certain value for isolated areas, but owing to the heavy plumps of rain which are commonly experienced from time to time in nearly every district, their value as a main anti-erosion measure for S. Indian tea estates is very limited.

Size of Spacing of Trenches.—The trenches, to be most effective, should be spaced along contour lines. No general rules for size or spacing can be laid down as these must vary under different conditions; they are best calculated by finding if the trenches are sufficient to hold the run-off water from the heaviest falls of rain.

Silt Pits.—The effectiveness of silt pits as an anti-erosion measure depends on :—

1. The percentage of rain water they can hold up.
2. The rapidity with which the water they hold up can be absorbed by the soil.

As a supplementary measure they have special value if staggered between other barriers (drains etc.) as they arrest water and are thus especially useful during heavy rains when the capacity of other measures is liable to be over-taxed. Their value is greatest under conditions of low rainfall of even distribution falling on a loose soil, but is limited by :—

- (a) their size,
- (b) their frequency,
- (c) the quantity of water they are required to hold up.

Their capacity for retention of water and collection of spoil is restricted to the pits themselves, and once they have become full of water (or spoil), they lose their purpose as run-off water can then flow unhindered over them. Their size and frequency are dependent on rainfall and soil type. A useful method under certain conditions, particularly if reinforced by a ground cover of vegetation.

Silt pits are not infrequently dug in the bottom of existing drains. Their value here is very limited because the velocity of water-flow in ordinary drains is such that only the coarser fractions of soil are deposited. In the event of a continuous stream running above these pits the fine particles remain suspended and are carried away.

Contour Platforms.—The formation of contour platforms is hardly a practical proposition for tea, and is a method usually restricted to tree crops. However, a short description of essential features is included here, as the method has use in the case of fuel clearings.

The most effective type of contour platform is one which has a reverse slope with the inner edge at least 1 ft. below the outer, and which is not continuous, i.e., sections are partitioned off by leaving small buttresses or bunds at intervals which will act as a means of stopping lateral movement of water.

Contour platforms which are of most value in areas of restricted rainfall and gentle slope can be reinforced and made more effective :

- (1) by digging silt pits at the back of the platform sections,
- (2) by establishment of ground cover.

Suitable plants for contour platforms :—

Centella asiatica,
Desmodium triflorum,
Indigofera sp. (low growing sp.),
 Grasses.

Cultivation.—It is unfortunate that in spite of the vast amount of work which has been done the world over, no satisfactory evidence exists to demonstrate beyond doubt the effect which stirring of the soil has on erosion. That opposite views are expressed is partly due to the fact that different soil

types respond in different ways. And account must also be taken of local climatic conditions.

Lowdermilk, who carried out extensive researches, holds cultivation to be one of the most important agencies in inducing accelerated erosion and 'unless special precautions are taken on sloping lands, the utility of soils for agricultural crops is destroyed'. An experiment carried out at Peradeniya in Ceylon showed a maximum of 18 tons per acre of soil eroded in forked land, and less than $\frac{1}{6}$ ton on unforked land. The particular experiment, however, is open to criticism.

As against this, other workers have obtained opposite results. One can presume that soil stirring has a good influence in as much as it affects beneficially absorption, percolation and retention of soil water. But while it may certainly have the effect of reducing surface water run-off, the loosening of the soil may lead to an increase in the total amount of soil removed, there being no fixed relation between amount of surface run-off and amount of soil removed.

While it is generally agreed that from the soil conservation viewpoint deep cultivation is better than shallow, yet on this point too there is disagreement, and it is worthy of note that at Sholapur results were obtained which showed progressive amounts of soil lost as the soil was deeper stirred. Land under natural grass or vegetation lost $\frac{1}{5}$ ton per acre. Removal of vegetation without stirring resulted in the loss of 27 tons soil per acre; land stirred to 4 inches depth lost 52 tons per acre. And here the average rainfall was only 26 inches. Deeper cultivation probably does not fit in with the best treatment for the plant itself whose root-system is liable to damage by deep soil stirring.

Placing of Soil Conserving Works.—The most effective lines for siting soil conserving works are contours. It is conceivable that with permanent crops already established, it will be inconvenient to keep the exact contour lines, and it is not always necessary to do so. While contour planting is most desirable for certain widespaced crops, e.g., rubber, it tends to complicate such works as harvesting, manuring and cultivation in the case of close-planted perennial crops, and so is not essential for planted tea. Yet, as far as possible, anti-erosion works should follow contour lines.

In deciding on the spacing of lines of conservation works and hence the distance between successive barriers, the following points are of concern:—

- (1) The steeper the slope the more closely lines of the same vertical interval should approach each other and *vice-versa*.
- (2) The more efficient the barrier in checking run-off water and retaining the soil it carries, the further apart the lines need be.
- (3) The more absorptive the soil, the further apart the lines.
- (4) The more efficient the crop, as a soil cover, and the thicker the crop is planted, the further apart the lines.
- (5) Other anti-erosion measures adopted. As a general rule, for land steeper than 25% (= 1 in 4 or approximately $14\frac{1}{2}^\circ$), distance between drains should not be more than 24 ft.

Slopes 5%–25% — at least double the above distance.

J. D. MANNING.

REPORT OF THE ENTOMOLOGIST

1940-41

Correspondence.—Letters relating to Entomological subjects numbered 137 received and 187 despatched at the Station, while 40 letters were received and 56 despatched during the Entomologist's stay in South Travancore. In addition to these, the monthly *Helopeltis* returns were received regularly from a number of estates throughout the year.

Advisory.—The enquiries relating to tea constituted, as usual, the major portion of the advisory work. The remainder of the enquiries related to shade trees, Red Gum, Cardamom and other miscellaneous subjects. The more important of them have been mentioned below under appropriate heads of crops.

Touring.—About a fortnight at the beginning of the year was spent in the Anamallais to conclude the unfinished part of the investigation on Termites undertaken in the latter half of March of the previous year. Subsequently, the period from June to August was spent in South Travancore in connection with work on *Helopeltis*.

Publications.—An article entitled 'Helopeltis—A Summary of information collected through replies to the questionnaire with comments thereon' was published in Paper No. 2 of the Department issued in October 1940.

An account of the nursery pests of tea and some of the other plants grown on tea estates has been written up and is awaiting publication.

TEA

Helopeltis.—Work on this pest was continued during the year and the progress made is briefly indicated in the following paragraphs:—

Pruning Experiment.—This experiment started on an estate in South Travancore has now run over a year. The incidence of the pest on the different plots was recorded monthly throughout the pest season and crop records of individual plots have also been kept for the entire period. The indications from these figures are as follows. Any relationship between incidence and treatment hardly exists. All plots, irrespective of treatment, appear to be infested to almost equal degree during a severe attack but the damage the bushes suffer and the rapidity with which they recover, as revealed by crop records, appear to vary with different treatments. The plots pruned at 18" have consistently yielded less than plots pruned at 24" and the latter have also shown some superiority over plots pruned at 30" with or without cleaning out. Cleaning out or non-cleaning out has made no difference in crop. It would be interesting to know what results will be obtained from this experiment during its second year. The combined figures should then throw further light on the question of how far hard pruning is justifiable in localities liable to severe *Helopeltis* attacks.

Pruning-cum-Tipping Experiment.—Started about the same time and on the same estate as the above experiment, the data are now available for a

year for this experiment also. Even here, the superiority of high pruning (in this case 27") over low pruning is again brought out in much the same manner as in the pruning experiment, but the height of tipping, whether 6" or 12", has not, on the whole, made any great difference either in crop or in the incidence of the pest. Such differences as have been recorded show no uniformity to enable any conclusions being drawn.

Trap plant.—The cuttings and young seedlings of the 'trap plant' referred to in the previous Annual Report (p. 13) were planted along edges of tea in 3 or 4 selected localities where *Helopeltis* was thought likely to thrive best and cause serious and prolonged attack on tea. They had not sufficiently established themselves during the last pest season to notice the effect they may produce by their presence in the vicinity of tea. This will have to be observed during the coming year.

In connection with the establishment of the 'trap-plant', the question whether *Helopeltis*, as the result of continuous breeding in tea, has become a biological race which may not take readily to its original food-plants, had naturally to be considered. A few feeding and oviposition trials were therefore undertaken with captured insects to decide this point. These indicated that insects caught on tea feed and complete their development and also oviposit on the 'trap-plant' and *vice versa*. It is therefore considered unlikely that this factor of biological race would act as a hindrance if, in other respects, the plant under trial proves suitable as a 'trap-plant'.

Questionnaire.—In response to the questionnaire issued in the early part of the year a number of estates interested in the problem sent in replies. These have generally indicated that more or less unanimous opinions are held in planting circles on most aspects of the problem, but that a certain amount of divergence of opinion also exists in respect of some aspects. The various points that were raised in the questionnaire have been dealt with in Paper No. 2 mentioned earlier.

One or two observations made by planters which came too late for inclusion in the above article may be briefly mentioned here. One of them refers to the intimate connection which is believed to exist between lack of soil aeration and *Helopeltis* attack. The water-logging conditions of the soil are said to interfere with the free flow of sap in the bushes and so render them liable to severe attacks of the pest. To obviate this, removal of sub-soil water is considered a very important step and very satisfactory results appear to have been obtained by digging short saps deep into the hillsides rather than long shallow side drains and by deepening the swamp drains twice a year. These, in my opinion too, are steps in the right direction; on estates where tea is liable to suffer from water-logging conditions, the importance and value of efficient drainage as a means of combating the pest cannot be too strongly emphasised.

Another observation was in respect of the possible connection between *Helopeltis* and another grass-hopper pest, *Orthacris* sp. On an estate in South Travancore where both the pests occur, though *Helopeltis* is of comparatively recent origin, it was reported that, curiously enough, *Helopeltis* was nowhere to be found in the area infested by grasshoppers and the converse was also reported to be true. The point was raised whether the grasshoppers in any way control *Helopeltis* by preying on the bug or its eggs. In answer, it must be mentioned that there has been no instance so far of any grasshopper preying upon *Helopeltis* and that the connection noted between the two pests is perhaps more apparent than real.

Plucking in relation to oviposition.—As plucked ends of shoots very often offer positions for egg laying, an endeavour was made to determine how far, if at all, oviposition on them is encouraged or discouraged by the mode of plucking adopted. Two types of plucking were considered, viz., (1) plucking two leaves and a bud, leaving a leaf above the fish leaf and (2) plucking to the fish leaf. Obviously, the stalks left in (2) will be much harder and more fibrous than in (1) and with a view to find out which type is preferred by the insect as being more suitable for egg-laying, a small duplicated experiment was undertaken wherein a definite number of bushes were plucked according to one type and a similar number according to the other. After each round of plucking 100 stalks were collected from each group and examined for the number of eggs laid in them. The data obtained over a period of four weeks did not reveal much difference between the two types of plucking. This was at a time, however, when *Helopeltis* was just starting, but, unfortunately, the experiment could not be proceeded with till such time as the pest became severe and egg-laying was at the maximum.

The condition of the pest during 1940-41.—A few observations in this regard may not be out of place here. In making these observations the monthly returns received from estates of different districts have been most useful. From them it would appear that the year, on the whole, was not altogether a bad one from the point of view of *Helopeltis* and that serious damage was limited to the period October-December. It is possible, however, that attacks have varied in severity in the two districts, viz., Central and South Travancore, but such variations do occur even within the same district. While some estates in Central Travancore described the pest as 'quite the lightest visitation' for several years, an estate in the Venture valley reported that 'the attack was the most widespread and severe on record'. Nevertheless, the outstanding feature of the year, admitted by all, was the late appearance of the pest almost everywhere. Even on estates where the pest appeared as usual in June, it did not appear to have multiplied to an extent causing economic damage during July and August. The attack of the pest, in general, began to be felt about September and increased during the succeeding three months, the severity reaching its maximum during December when greatest damage was done. Thereafter, signs of the pest declining were evident but, unlike in normal years, the pest appears to have persisted even in February and, in one or two places, in March also. This is perhaps the result of the late attack combined with favourable climatic conditions which prevailed after December.

The Rani valley appears to have been practically free from the pest during the year under report, but the situation in Mundakayam is not known, as no reports have been received from that district.

Termites.—The observations made on these pests in the Anamallais have been mostly dealt with in the last Annual Report and mention may be made here of the laboratory trials conducted with Cowan's White Ant Exterminator and Paris green against *Kaloterme* sp. In the first place, varying numbers of insects were dusted lightly with Paris green and Cowan's powder respectively and their subsequent examinations indicated that in both cases the mortality was 100 per cent by about 48 hours, thus demonstrating the fact that the insects which actually get a coating of the dust are invariably killed. But to determine whether a few treated insects are able to infect the other individuals of the colony and so destroy the entire colony, a second trial was made, employing both these insecticides and also keeping a lot of insects as control. These trials indicated that Cowan's powder was

somewhat superior to Paris green in that the deaths among the insects treated with it were quicker and greater in number. Paris green appeared to be definitely slower in action, the kill obtained with it being only about 60 per cent as against 89 per cent with Cowan's at the end of 48 hours. Later, this difference was gradually made up until at the end of 4 days the kill was about 89 per cent with Paris green while it was about 96 per cent with Cowan's. At the end of 6 days, however, whatever difference there existed previously between the two treatments was no longer to be seen, the mortality in both cases being approximately 98 per cent. It is worthy of note that individuals of the soldier caste proved more resistant than nymphs in both treatments but this feature may not seriously detract the value of either product, as, if the other members of the termite colony are adequately dealt with, it may be expected that soldiers by themselves will not survive long and may eventually perish.

It now remains to consider the economics of treatment with the two products. Cowan's, as already pointed out, is decidedly the quicker of the two in dealing with the insects and to that extent it may be considered better. But this advantage is greatly offset by the very expensive nature of the product. Paris green, on the other hand, is considerably cheaper and though comparatively slower in action, may perhaps be expected to give ultimately the same result as is obtainable with Cowan's powder.

Trials were also made with Cowan's against the mound-building, species of termite, viz., *Termes (Cyclotermes) redemanni*, Wasm. occurring on the Station, but the results obtained have been inconclusive. The trials are being repeated.

Termites continue to be a problem in the Anamallais and several enquiries were received during the year concerning the various species occurring there. It is needless to mention them again here as they have all been referred to in previous Annual Reports. The specific identity of *Kaloterms* attacking living tea bushes in that district has, unfortunately, remained undetermined yet, owing to experts in the British Museum being engaged on other duties.

Shot-hole Borer.—No case of attack by shot-hole borer was reported during the year, but, through the courtesy of Dr. Beeson, the Forest Entomologist at Dehra Dun, an examination was possible of a series of beetles collected from estates near Vandiperiyar over a period of several years. This examination revealed that the majority of the specimens showed a mixture of features of *fornicatus* and *fornicator*. The typical *fornicatus* features were possessed by a small number of individuals while the number of individuals conforming to the *fornicator* type was equally small.

The specimens of the beetle were all collected from tea bushes at different times and there could be little doubt that the beetle had bred in them for a number of generations. From the above examination it would appear that the insect, even after several years' breeding in tea (ten years as far as authentic records go and probably many more than this), has not produced a race which is exclusively *fornicator*. The examination shows, however, that continuous breeding in tea does produce modifications tending in that direction. Dr. Beeson considers that the condition of the tea bush, the climate, etc., are probably more influential in Ceylon than they are in Travancore and reaches a practical conclusion that 'there is little danger of introducing and establishing a particularly "virulent" race from Ceylon'.

Nettle-grubs.—Except for one or two stray instances of grubs noticed on the Station, the year was conspicuous by the absence of report of nettlegrub damage from any of the tea districts of South India.

Mites.—Purple Mite, *Eriophyes carinatus*, Green, constituted an important pest of tea during the year and several reports of its occurrence were received from different districts. The extreme dry weather experienced for two years in succession was probably responsible for the mite to come into prominence. It is noteworthy that this mite which had hardly been noticed on the Station tea in previous years was very prevalent during the year. For much of the information on this subject we are indebted to Ceylon where it is generally held that adverse climatic conditions bring about attack on tea and that on the advent of good growing conditions the bush will shake off the attack. Special control measures are normally considered unnecessary but for dealing with persistent attacks, sulphur dusting is recommended.

Scarlet Mite (*Tenuipalpus obovatus*, Down.) was prevalent to a certain extent on tea in the Station area during the dry months and it was also noticed on the neighbouring estates. Not being of common occurrence and also in view of its almost inconspicuous nature, the pest is rarely detected and its damage is generally thought to be due to other causes. From available evidence it is not considered improbable that this mite has a wider distribution and causes more damage than at present realised.

The Red Spider (*Tetranychus bioculatus*, W-M.) was also in evidence during the year but no report of serious damage was received from any district. It was not unusual to find a combined infestation of all the three above-named mites on the same bush.

Red Coffee Borer.—(*Zeuzera coffeae*, Nietn.). This insect was reported to have caused some damage in the Nilgiris and in South Travancore. In the latter district the attack was on the nursery plants. Although a minor pest as a rule, this borer can cause serious damage in the nursery when it may be dealt with in the following manner. All dead and dying plants are first of all removed and burnt with a view to destroy the caterpillar or pupa present inside them. Then the plants in which the attack is still confined to the top portions are cut back to sound wood and the caterpillars encountered while so doing are destroyed. In plants where the main stem is bored down to a depth below the customary level of stumping, it is no doubt possible to kill the insect by introducing a flexible wire or a small quantity of carbon bisulphide or petrol into the gallery, but, before doing so, it may be well to consider whether such plants will prove to be suitable material for planting out. Should there be any doubt about this, their treatment is not worth while and the plants may be uprooted and burnt.

There is unfortunately no method by which to prevent attack of this borer in the nursery. However, the insect is a low breeder and if a careful watch is kept over the nursery and prompt measures are applied at the first signs of attack, the pest can be effectively kept under check.

Thrips.—A case of thrips injury not so far noticed in South India came under observation on an estate in South Travancore. The infested bush had ceased to flush and the leaves exhibited a marked curling which was not unlike that caused by *Anaphothrips* spp. reported as occurring in Java.

A report of stunted growth of tea was received from an estate in the Nilgiris and from an examination of the accompanying specimens, thrips

attack was suspected. Similar symptoms were also observed on several bushes on another estate in the same district. Adequate evidence could not, however, be obtained to connect thrips definitely with the condition of growth observed on the bushes but the possibility could not be overruled. The matter requires further investigation.

Cutworms.—These caterpillars were reported from the Nilgiris and in one instance were the cause of extensive damage to young basket plants in a clearing. It was pointed out that plants protected by shade baskets suffered most, which is presumably due to the greater shelter afforded by these baskets to the insects during the day. When the report was made, the caterpillars were already full grown, some had pupated and others were shortly about to do so. It was suggested therefore that the pupae which are to be found in the soil around the plants be collected and destroyed. To deal with the caterpillars which may still be active and causing damage, a poison-bait was suggested. As nothing further was heard of the trouble, it is hoped that these measures were found adequate to bring the pest under control.

Bag-worm.—An attack of *Psyche vitrea*, Hmps., a species of bag-worm, was reported from South Travancore. The caterpillars were stated to be found in abundance on tea under the shade of *Albizzia*. Presumably, the infestation originally started on *Albizzia* and later spread to tea. Short of pruning the infested bushes and burning the prunings, hand-picking appears to be the only method of controlling this pest. Other methods such as spraying are hardly likely to succeed, because the caterpillars seem to be extremely resistant to stomach poisons such as Paris green and similar compounds; a contact insecticide like kerosene emulsion is also useless in view of the protective case possessed by the caterpillars. Since the cases are easily seen, hand-picking should not be very difficult, but care should be taken that old and apparently dead cases are also collected as they may contain eggs. The collected cases may then be burnt.

White Grub.—The prevalence of white grubs in the soil under mature tea in the Nilgiris is believed in certain quarters to be detrimental to tea in that the grubs may feed on the tea roots and thereby render the bushes unthrifty. Much of the unthrifty tea noted in this district is thought as most likely to be the result of white grub damage. It is difficult to say off-hand whether or not white grubs are responsible for the damage attributed to them and the subject requires thorough investigation at a time when grub activity is at the maximum.

Eelworm.—The root-knot eelworm continues to be a problem in nurseries, but the importance of choosing suitable soil free from eelworm infection before laying down a nursery appears to have been more generally realised than before and several estates have sent in samples of soil and weeds growing thereon for eelworm examination. Since a satisfactory method is yet unknown of controlling the pest when once it has made its appearance in the nursery, it is hardly necessary to emphasise the value of preventive measures, such as soil sterilization by heat or chemical, eradication of weeds, maintenance of good drainage and avoidance of over-watering.

Rats.—Apart from the damage they cause to older nursery plants by gnawing their roots, these animals seem to be capable of attacking freshly-germinated seedlings. In a case which came under notice, the seedlings in a basket nursery had been pulled out of the baskets and the cotyledons devoured. Bananas poisoned with strychnine were laid out as baits which

were taken by the rats and further damage ceased for some time. A change bait consisting of barium carbonate laid out a few days later was, however, untouched by the rats, but running a line of steel traps was found useful.

In addition to the foregoing, the following insects were also reported on tea : Tea Aphis, Leaf-roller, a Lasiocampid caterpillar (*Taragama dorsalis* ?); Twig caterpillar (Geometrid), cricket, fly maggots in tea seed and ants in germinating beds.

GREVILLEA

Xyleborus semigranosus Bldf. and other allied scolytid borers were frequently reported from different districts, but mainly from the Anamallais. As these borers usually infest unthrifty trees and are also to be found on dead or dying trees, they not unnaturally create suspicion that they may be the cause of death of the trees. But on fuller investigation it will generally be found that that suspicion is unfounded and that the real cause of death may be root disease or the unthriftiness of the trees may be the result of adverse climatic or soil conditions. When once the vitality of the tree is reduced, the latter becomes liable to infestation of these borers. Their attacks have therefore to be looked upon as purely secondary and they serve as indications that the tree is not in full vigour.

Cutworms were reported as attacking *Grevillea* nurseries in the Anamallais. Hand-picking, the spreading of leaf-baits such as cabbage and sweet potato leaves over the beds and the employment of a poison-bait consisting of sodium fluoride are some of the usual methods of control. The adoption of one or more of the above methods according to the severity of the pest should help to rid the nursery of cutworms within a short time.

ALBIZZIA

The question of borer attack on *Albizzia moluccana* in Peermade received further attention during the year, mainly with a view to advise on any control measure that might be found useful. An investigation from an entomological stand-point has not been undertaken yet, but from correspondence with the Forest Entomologist at Dehra Dun who has considerable experience of forest insects; several facts concerning this borer have come to light and they are briefly indicated below.

The borer is tentatively identified as *Xystrocera globosa*, Ol., on the basis of larval characters. This identification requires to be confirmed after an examination of adult beetles.

The factors governing the attack are said to be :—

1. Lack of vigour of the trees and their consequent inability to resist repeated oviposition.
2. Abnormally high population of the insect in the locality as a result of excessive breeding.

With regard to the first factor, the weak condition of the trees may be the result of branch canker or change in soil drainage or soil nutrition, in which case, treatment for branch canker, manuring, counter-erosion or weeding is suggested as a remedy. But opinion based on local observation is inclined to the view that the attacks are not always connected with the vigour of the

trees and that perfectly healthy trees growing under vigorous conditions do not escape infestation.

Should the attacks be the result of the second factor, dead and attacked trees are recommended to be cut out and destroyed or utilised as fuel. In this connection, it is also necessary to find out whether the insect is breeding in fellings of miscellaneous jungle or fuel wood nearby the estate, as this point is intimately connected with the question of control of excessive breeding.

The application of sprays or deterrents may afford a means of protection but before considering this form of treatment, it would be necessary to determine the emergence and oviposition periods of the beetle.

In Java, a 10 per cent solution of paradichlorobenzene in kerosene injected underneath the bark of infested trees is stated to have given satisfactory results in the control of an allied borer, *X. festiva* attacking *Albizzia* in that country. But this method when tried in Peermade was reported to have practical limitations in that the infested areas on the tree were difficult to locate without stripping the bark.

To sum up, this borer problem, on the whole, is one on which we have very little precise information at present to guide us to decide on any definite method of control. There are several points requiring elucidation such as :—

1. Correct identification of the beetle.
2. Causes contributing to lack of vigour of the trees.
3. Possibility of excessive breeding, including the question whether or not the insect is breeding in jungle fellings.
4. Emergence and oviposition periods of the beetle.

A Hepialid borer which is probably a species of *Phassus* was reported as attacking young *Albizzia* trees in the Anamallais. This borer has a wide distribution in South India and is known to attack several plants such as Tea, *Gliricidia*, Red Gum, *Crotalaria*, *Casuarina*, *Lantana* and some of the garden plants. It may be controlled in the same manner as Red Coffee Borer. Injection of a small quantity of a mixture of chloroform and creosote into the tunnel of the borer has given good results and may be particularly useful in cases where it is not desired to cut the tree below the region of attack.

RED GUM

Reports of termite damage to Red Gum seedlings were very prominent during the year. The trouble appears to have been felt in more than one district. A case in Nilgiri-Wynaad involving a 20-acre clearing was investigated by the Tea Scientific Officer who came to the conclusion that termites, identified as *Termes fcae*, Wasm., were definitely responsible for the damage. Based on the observations made on the spot he has suggested several control measures which include (1) multiple planting, i.e., putting several seeds to germinate in each basket and putting 2 or 3 baskets in each pit in the clearing, (2) pre-treatment of baskets with a solution of sodium arsenate or zinc chloride, (3) watering the pits with Hookah water (extract of tobacco leaves) and (4) the use of a poison-bait employing Paris green or sodium arsenite. Full details of these measures are given in Paper No. 2 of the Department issued in October 1940.

It was suggested in some quarters that a layer of sand spread all round and below the seedling in the planting hole might help to keep off termites. This suggestion is being tried out on the Station where a small scale experiment has been laid out. No infestation has been observed so far but it is too early to judge the result.

DADAP

The 'ringer' beetle (*Sthenias grisator*?) referred to in the Annual Report for 1936-37 was noticed to be particularly prevalent in the Station area, causing considerable damage to young Dadaps during the period October—January. The adult beetles have a longevity extending over a few months during which period they may destroy a large number of branches by girdling. Eggs are deposited in such branches and each branch may eventually give rise to as many as a dozen beetles. March appears to be the peak month for emergence, though beetles may commence to emerge from February and continue till April. Since active oviposition was being observed in October also, it seems probable that an emergence of beetles takes place during the rainy months. Should it be so, there are two generations in a year, though they overlap each other.

The adult beetles, although possessing wings, are loathe to fly but simply drop to the ground on disturbance or cling harder to their support. The life-history and bionomics of the pest as far as they relate to devising a suitable control measure are being studied.

Another Cerambycid borer, smaller and more slender than the 'ringer', lays its eggs inside the tender terminal parts of branches of Dadaps. The larvae on hatching bore down the branches which may eventually die back in much the same manner as with an attack of the moth shoot-borer, *Terastia meticulosalis*, Gn. The identification and further details concerning the insect are receiving attention.

Other insects noted on Dadaps during the year include *Terastia meticulosalis* boring in branches, *Mylocerus* sp. (weevil), *Orthacris* sp. (grass-hopper) and a Chrysomelid beetle feeding on the leaves and the sucking insects, *Eurybrachys tomentosa*, Fb. and two species of Membracid bugs. None of these, however, was serious enough to cause any appreciable damage.

An instance of attack by the root-knot eelworm was observed on Dadap planted amidst tea. The tree was apparently healthy and did not show any ill-effects as the result of attack. The roots of mature tea in its vicinity revealed no indication of infection.

CARDAMOM

The hairy caterpillar (Eupterotid), thrips, a coleopterous grub and a fly maggot were reported on Cardamoms during the year. The last two were stated to be attacking young seedlings, the grub actually killing the plant outright and the maggot destroying only the shoot but allowing fresh buds to come up from below. In the absence of suitable material for breeding the adult stages, the correct identifications of these insects have, unfortunately, not been possible.

MISCELLANEOUS

The *Crotalaria* growing on the Station was subject to the depredation of the Hepialid borer, *Phassus* sp. ? already referred to under ALBIZZIA. It is a polyphagous insect attacking a variety of plants. Control measures remain the same in all cases and as the borer is a slow breeder, there should be no difficulty in keeping it under check. March-April is believed to be the period when the moths emerge and lay eggs. The eggs are white at first but turn black later and are presumably broadcast in large numbers over the ground when the moth is flying.

The Lycaenid butterfly, *Polyommatus boeticus*, Linn., was responsible for a certain amount of damage to pods of *Crotalaria*. The eggs of this butterfly are laid on the flower buds and the larvae on hatching bore into the young pods and feed inside on the seed. If the plant is grown for green manure, topping before the plant has commenced to flower would control the pest and this measure is of particular value in preventing the infestation from spreading to other places, especially if there is any area in the neighbourhood where this plant is being grown for seed.

Tephrosia vogelii grown on an estate in the High Range was attacked by the root-knot eelworm. The galls characteristic of this worm were noticed very prominently on the roots, the heavy infection that was noted being probably an indication that the plant is very susceptible. Though *T. vogelii* has been reported in Ceylon as one of the seriously attacked plants, this is the first instance of eelworm infection on *Tephrosia* that has come to our notice in South India.

Acknowledgements.—Grateful acknowledgements are made to the Forest Entomologist, Dehra Dun, who very kindly undertook to examine the insect specimens forwarded to him and also gave valuable suggestions on several entomological problems referred to him.

It is again a pleasure to record my appreciation of the accommodation and other facilities provided by Mr. A.P.D. Lodge during my stay on Ambanaad Estate. I have also to acknowledge with gratitude his co-operation in the conduct of experiments laid out on his estate.

Thanks are also due to the Managers of estates in Central and South Travancore and Mundakayam who sent in returns of *Helopeltis* statement.

S. ANANDA RAU,
Entomologist.

REPORT OF THE MYCOLOGIST

1940—41

Advisory.—One hundred and fifty lots of specimens were received during the year, a large number of these in connection with investigations on starch reserves. *Grevillea* foliage has claimed an appreciable number of enquiries. Physiological troubles in Nurseries have also received considerable attention.

Touring.—During the month of July (1940) a short visit was paid to an estate in the Wynaads in connection with defoliation in *Albizzia* trees. Frequent visits, at first weekly later fortnightly, were found necessary to a neighbouring estate as a result of an outbreak of *Rosellinia* root disease. To investigate into the causes of deterioration in *Grevilleas* in the High Ranges a visit was necessary and undertaken during the last week of February (1941).

General.—Apart from the *Rosellinia* disease that had spread over a large part of an estate, no serious outbreaks of disease were reported. Black rot (*Corticium invisum*) appears to be serious in the Anamallais.

TEA

LEAF DISEASES

Black Rot.—Reports from the Anamallais indicate that Black rot of leaves due to attacks of *Corticium invisum* has assumed a serious aspect. A few years back, (1934) the disease was considered to be serious in fields due for pruning, but this position has now changed and the disease seems to be serious in even first year fields. In the earlier reports of this department and in the report made subsequent to a visit of the district, the serious nature of Black rot and of the erroneous impression then prevalent that bushes would normally recover and flush with an easing of the weather conditions even when no control measures were put into effect were pointed out. It is more than likely that the latter impression has greatly contributed to the worsening of the situation. Information was available that on such of the estates as had taken to spraying, the disease was not so serious, but it is unfortunate that even these estates gave up spraying because their neighbours failed to control the disease when such existed.

However, some of the estates have now come forward to conduct disease control operations and plans have been laid out for the purpose. As pointed out in an earlier report (1939-40) whether we can do away, as in N. E. India, with the operation of removal of diseased material of the previous season should form one of the aspects for investigation in the proposed experiments in this direction. It is hoped that the results obtained from experiments would throw considerable light on the many aspects of the disease as it occurs in South India, as also help to remove the impression on the question of control measures against this disease.

STEM DISEASES

No reports were received on the position of stem diseases during the season under review.

ROOT DISEASES

On an estate in the Nilgiri-Wynaad a serious outbreak of Black root rot occurred, and the measures taken against the control of the disease are briefly discussed here. This apart, there is nothing of importance under this head.

Black Root Rot, (*Rosellinia* spp. *R. arcuata* & *R. bunodes*).—Hitherto, attacks of *Rosellinia* were considered by some to be more common in tea in the higher elevations, although to a lesser degree the disease occurred in the lower elevations also. There is sufficient evidence now to indicate that elevation makes no difference against this disease, either in virulence or mode of attack.

The presence of decaying organic matter is essential for the development of *Rosellinia*. The fungus apparently prefers a medium where a complete decomposition has not taken place because of the refractory nature of the decomposing material. For instance a thick bed of *Grevillea* foliage and large quantities of woody prunings would take a longer period to decompose than the more easily decomposing dadap foliage and less woody material. It was under the former conditions, viz., thick spread of *Grevillea* foliage and woody prunings that a serious outbreak of Black root disease occurred. Both vegetative growth and reproductive material appeared to have found very favourable conditions for development.

Of climatic conditions, continuous wet spells were definitely known to have encouraged the spread of the disease, more particularly the conidia or the imperfect spores of the fungus were found developing on the decaying material under shade and in misty humid conditions. Small patches of fungal growth in greyish white masses carrying the conidia were very often seen on the particular estate on misty days during the wet season. Such growths, however, were uncommon when heavy precipitations of rain were recorded and in areas that were more exposed.

Soil Acidity and Disease.—The worst attack occurred in an area found to be neutral to alkaline in reaction, but soils that were definitely acid also had the disease. All that can be said therefore is that the organism thrives very well under neutral or alkaline conditions but that it can progress (*is tolerant*) even under fairly acid conditions.

Burial of Prunings.—The question arises if all organic matter is susceptible, and this unfortunately appears to be so, although it is possible that organic material that rots away quickly has less chance of carrying the disease organism. From the point of view of the disease, incorporation into the soil of woody matter and slowly decomposing leaf (*Grevillea*) material favours the development of the fungus. While organic matter of this type improves the tilth and fertility of the soil, it also seems to bring root disease in its wake. The safety appears to lie in eliminating this source of infection and of spread in areas where root disease—especially *Rosellinia*—has been diagnosed to be present.

Normally, it is rather difficult to obtain fructifying material of most of the root disease organisms, but the presence of large quantities of incompletely decayed woody tea prunings in the soil had probably helped the fungus to produce as much of the fructifications as it could. Within a year of burying the prunings, practically every piece of wood so buried had developed the black shot-like fructifications of *Rosellinia*. Some of these fructifications were smooth with a rather raised mouth belonging to *R. arcuata*, others—but

in equal numbers—had a rough wart-like appearance, these latter belonging to *R. bunodes*.

Types of attack.—The most common impression we have of root disease invasion is that the concerned organism spreads from the roots upwards, the disease having started in the soil through buried roots or stumps that had already been diseased. In the case of attacks from *Rosellinia* this appears by no means the only way. The infection has been found to start from near the collar region (sometimes above) and spread both upwards towards the stem and downwards towards the roots.

Since a large part of the bush, when the attack proceeds from above downwards, is apparently healthy looking, and normally flushing, the impression is created that the disease is confined to the branches; this, however, is not always the position. Not only have all the branches a covering of the greyish black fungus (a few of the branches also show cankers), but the infection will be found to have spread lower down and below the collar region to the roots. To make out the latter type of infection it is essential to remove the soil near the collar and where necessary expose the roots to some extent.

The actual damage in the earlier stages is not typical of root disease but has greater resemblances to the characteristics displayed by certain of the stem diseases. Such a condition does not, however, continue for long. The fungus grows towards the roots and causes the death of the entire bush when alone the presence of root disease is suspected and control measures adopted by the removal and burning of the diseased bush and placing an isolation trench.

Control measures.—Since in the earlier reports, control measures against attacks taking place through root infection, i.e., from within the soil through the roots have been considered, there does not appear to be any need for a further consideration of this aspect. In any form of attack (whether from the roots or from aerial parts) it is, however, imperative that the sources of infection wherever existing should be thoroughly removed if success has to attend such control measures. It is with such an object in view that in recent times greater reliance is placed in tracing the diseased roots to their extremities for subsequent destruction than in the earlier method of trenching.

Mention has been made that in instances where the attack starts from the collar, the affected bush shows apparently for sometime no indication of root infection except for one or two branches dying out. Can such bushes be saved before the infection spreads to the other parts or before they are killed?

Below are given the measures that were adopted towards saving the bushes when *Rosellinia* attacks were present on some organ or other of the bushes. It must be mentioned beforehand that the time that has elapsed after the treatments were meted out has not been sufficient yet to establish conclusively the success of the treatments. However, as a result of periodic visits, observations appear to indicate that in nearly ninety per cent of the cases treated, fresh healthy growth has been made without the new growth having any indications of the disease. If the disease had persisted in the treated bushes, it was probable that recovery would not have been accomplished, and deaths due to spread of infection would be manifest. The reaction of the treated bushes and their subsequent recovery have been under constant observation and this will continue till the next rainy season. For, it is

possible that the fungus if it has been persisting might again become active under favourable climatic conditions. This report should therefore be taken to be a preliminary one intended to convey some idea of the differing conditions under which this disease may occur and at the same time suggest a possible method of control under those circumstances.

The first step towards control of *Rosellinia* attacking through the aerial parts—the branch and the collar—should aim at clearing the ground around the perimeter of the bush so as to make observations and later treatment easy. Weeds and mulch, as also buried prunings should be removed from the affected areas and the collars of bushes exposed by unearthing to such depths as to show any fungal growth on the plant organs. It may often be necessary to expose part of the root system if the fungus has extended its activities over this area.

The disposal of the mulch and buried prunings should be attended to with great care, as otherwise, the fungus may still flourish and prove dangerous again. It is, however, possible to minimise temporarily at least, the chances of infection from this source by scorching the collected weeds etc., with a blow lamp and removing them for thorough burning, after the more important disinfection of the bushes has been accomplished. Repeated searches over the same areas for buried prunings is essential if their removal at one time is impossible. Whether such repeated rounds are necessary or not depends upon the presence of the prunings in the area even after the first operation. It, however, appears advantageous to go over the fields a second time to make sure that all infective material has been removed.

An examination of the bushes will show the extent of invasion of the parasite on the host. Treatment has to depend upon whether or not the fungus is only superficial or has invaded the host tissue. If the fungus is growing only on the surface, the underlying bark and the wood should be green and healthy. Also there should be no unusual development of lenticels on the surface. (The lenticels are longitudinal scars resembling the 'eyes' of the potato tuber.) In all cases, where the fungal growth is only superficial it may just suffice to treat the affected area with a fungicidal mixture with or without scraping off the superficial mycelium. It is absolutely essential that whatever fungicide is employed, it should reach all the crevices near and over the entire surface of the affected part; the application of the fungicide must be thorough. It may often be necessary to scrape off adhering particles of soil before the fungicide is applied. This may conveniently be done either with water or mere rubbing may do if the soil is sufficiently dry.

When the fungus has invaded the tissues of the host, a more drastic measure is needed, requiring the cutting out of all invaded or dead tissues to clean, healthy wood. The invaded tissue can be made out by (1) the occurrence of numerous lenticels on the surface of the bark when the affected part is not dead, (2) the death and discolouration of the tissues, especially a discolouration of the wood, (3) the presence between the bark and the wood of star-shaped radiating fans if *R. arcuata* or when *R. bunodes* the occurrence of longitudinal, black to greyish black streaks and dots in the wood, and (4) the formation on exposed surfaces of dead roots or dead aerial branches small spherical shot-like fructifications. The fructifications are smooth with a prominent mouth in the case of *R. arcuata* but are warty and rough in the case of attacks from *R. bunodes*. The extent of cutting out depends upon the extent of attack. It is possible that only the aerial branches require to be pruned off or the pruning might have to extend to the collar or even lower

down on the root tissue. Subsequent to the removal of diseased tissues from the still living host plant the latter is to be protected with the fungicide.

Especially when, because of the parasite invading the host tissue, drastic pruning has been necessary, a second and subsequent rounds of examination for possible persistence of the parasite on the rest of the host plant are essential. Experience has shown that the fungus shows up on the treated surface some time after treatment—a month or two later—necessitating further excavation and unearthing of the soil in order that the fungal growth may be removed or killed on such bushes. It is possible that the growth presenting itself after a time is due to (1) failure to detect the presence of the fungus by insufficient unearthing, or (2) it may be due to the fungus-invaded tissue not being removed at the time the plant was pruned for disease. It is assumed here that the infected prunings have been removed prior to adopting the other control measures.

To begin with, the possibility of a two-percent solution of caustic soda, controlling the growth of the fungus on the host tissue was tried. It was found that this had no effect on the fungus. In addition two disadvantages resulted by the use of caustic soda, viz., (1) the wash running down the stem caused the soil near about to turn definitely alkaline and (2) in certain cases (probably because of hard rubbing) the bark had been injured so as to cause the exudation of a dark red liquid from this tissue. Further trials with this substance were discontinued. A one-percent Burgandy mixture was given an extensive trial and results to date even with a single application have been very encouraging. Not only has the Burgandy mixture controlled the disease, but it has had a sort of tonic effect causing the formation of more buds on the treated surface. The buds have since opened and grown into good healthy shoots. If the disease had persisted or if the infection was from the roots, this recovery according to the present observations would not have been possible.

It will be seen that in cases of infection from other than the root system, more thorough work, and greater care is a pre-requisite if uprooting due to subsequent death from root disease has to be avoided. The efficiency with which the many details have received attention will be reflected in the recurrence or absence of attack during the succeeding months. It is possible that where infection was deeper than first located, the fungus shows up after a time. Such recurrent cases should receive attention through a gang going round at regular intervals meting out the requisite treatment as and when such becomes necessary.

Necessarily this second form of attack becomes *apparently* more costly than disease caused through root infection. It also means a co-ordination and thorough organisation of work to proceed systematically and in an uninterrupted manner. Constant inspection of all treated bushes should be an essential feature of the programme. Although actual figures are yet not available, treatment in the manner indicated here appears to have cost from between Rs. 20 to Rs. 50 an acre depending upon the intensity of attack and the amount of ground work that was necessary as a result of buried prunings. More than a hundred acres with varying intensities of attack have come under this treatment. Placing a value of 8 annas on a tea bush, the cost appears to have been amply repaid.

As earlier stated, the position regarding the disease after the above control measures were put into effect still requiries to be watched. However, clear indications exist that even after an interval of nearly seven to eight

months, the disease has been checked and the number of casualties reduced to negligible proportions. The recovery that has taken place in severely-pruned and subsequently Burgandy treated bushes also indicates that so far as these bushes go, they have been freed of the invasion of the parasite. It is hoped that further observations that are being made will be as encouraging as they have so far been.

DISEASES OF NURSERIES

Collar Ringing.—In some consignments of nursery plants received from a group of estates, a peculiar feature that had not so far come to be noticed was met with. The damage to these plants had resulted from a 'ringing' of the stem at about an inch from above the collar. The ringed plants had died. The 'ring' itself extended over a length of about half an inch. The roots of these plants were healthy and no organism was found to which to attribute the damage. Evidence so far available was insufficient to locate the cause of the 'ringing' of these plants. The trouble is probably physiological.

'Bitten off' Disease.—Enquiries on the subject have been more frequent. In most of the cases the damage to the root appeared to have been caused by soil conditions and over-watering.

An article on this subject was contributed and published as part of Paper No. 2 of this Department.

PHYSIOLOGICAL (Starch Reserves)

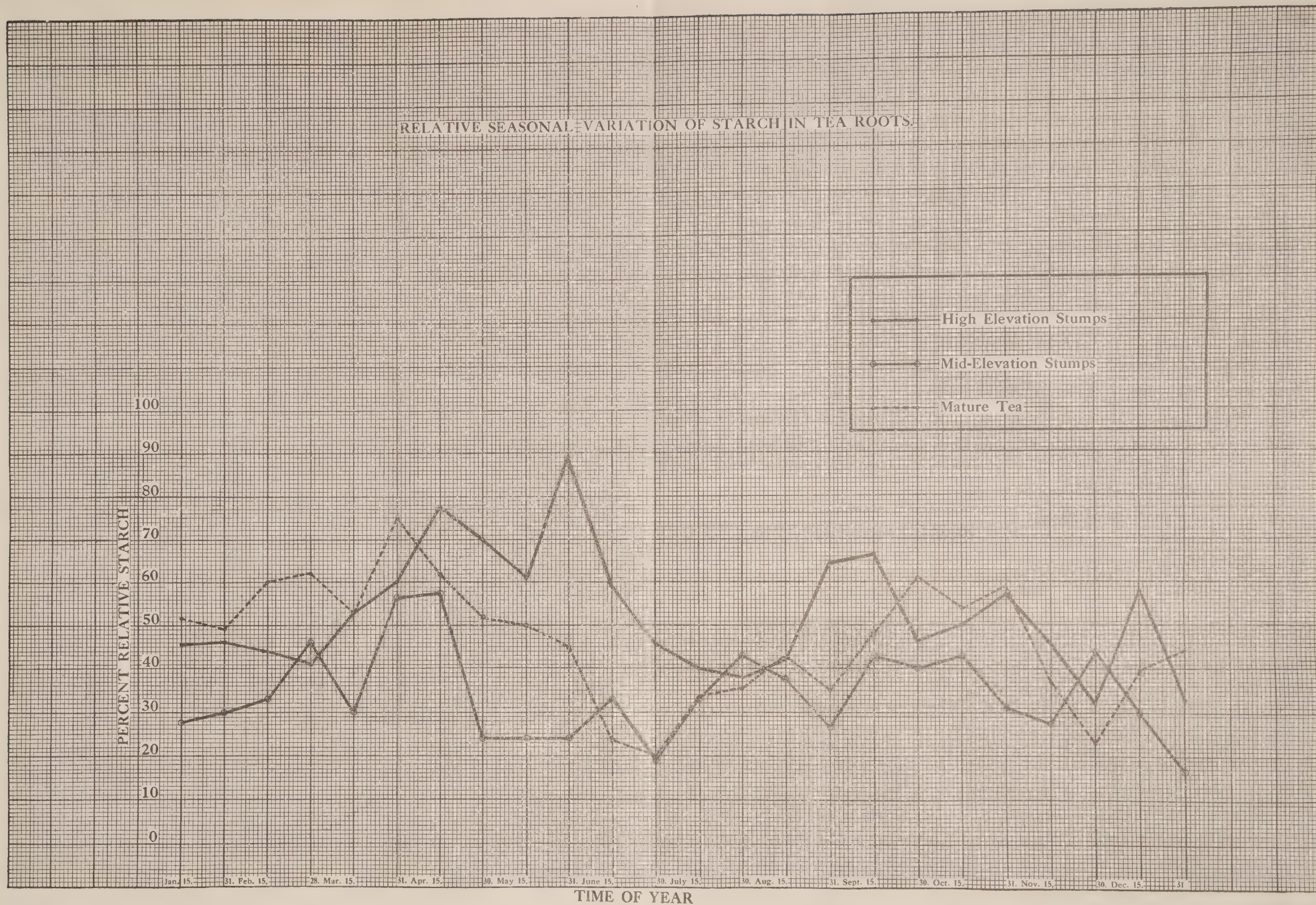
Mention was made in last year's report, of work of a physiological nature which was designed to establish the relation between root reserves (in the form of starch) and success in (1) supplying or replanting and (2) pruning.

At the time the work was taken up it was thought that the method of carbohydrate determination adopted would answer the purpose; the results obtained, however, proved that under certain conditions this visual test was not always a reliable guide in determining the amount of reserve material*. Moreover the valuation of the test depended too much on the personal factor for it is possible that the same sample valued by two judges gives a varying result. Thus although the visual test is reliable as a rough guide in the field and in dealing with large numbers, the results obtained lack scientific precision particularly when dealing with small numbers of specimens.

After considerable experimentation a more precise method of analysis is now being used. The total carbohydrate is being determined on accepted lines with certain modifications to suit our conditions. As the new method has not been worked over a full cycle, only results obtained by the visual test method are presented in the review of the work now presented.

* Starch when treated with a weak solution of iodine turns blue. The darker the colour so produced, the larger the amount of starch present over a given surface of the root. The darkest surface is placed at 100 and the one that does not change colour on treatment with iodine is placed at zero. Between these extremes, depending on the intensity of colour and area of coloured surface, the treated root surfaces are classified as 100, 90, 80 up to 10. The valuation expressed here as percentages is therefore arbitrary.

FIG. 1.



Reserves in Tea Stumps.—Tea stumps on which the tests were conducted were grown at two different elevations; one set at 6000 ft. and another at 4000 ft. Since metabolic activity is not so vigorous at the higher elevations as in the lower elevations, (the depletion of reserves in the two elevations would vary), it would have been desirable to have had specimens from the same jat of tea grown at both elevations. Unfortunately this was not possible. The stumps from high elevation were of hybrid origin, while those from mid-elevation were a variety of Manipuri.

The average starch distribution for three sets of material (1) High-elevation stumps, (2) Mid-elevation stumps and (3) Mature tea, is given in the two accompanying tables, and from the figures the comparative curve of variation has been drawn (Graph 1). Recordings were made on 15th and 30th of each month.

Table 1—Average Fortnightly Starch (visual) values in roots of Tea Stumps.

Month	Percent Starch			
	High-elevation Stumps		Mid-elevation Stumps	
	15th	30th	15th	30th
January ...	45.5	46.0	27.7	30.0
February ...	44.4	41.1	33.3	46.6
March ...	53.3	60.0	30.1	56.6
April ...	77.7	70.0	57.7	24.4
May ...	61.1	88.9	24.4	24.4
June ...	58.8	45.5	33.3	18.9
July ...	40.0	37.7	33.3	43.3
August ...	42.2	64.7	37.7	26.6
September ...	66.6	46.6	43.3	40.0
October ...	50.0	57.7	43.3	31.1
November ...	45.5	32.2	27.7	44.4
December ...	57.7	33.3	30.0	16.6

In general all the three curves show definite periods of fluctuation, in other words there is a seasonal fluctuation in starch reserves of both stumps and mature tea in bearing. The average starch content in the high elevation stumps has never reached a lower figure than 32 per cent and this in December. During the rest of the year the average of reserves has been maintained at more than 42 per cent. The mid-elevation stumps have always shown a lesser amount of reserve and reach a minimum of less than 20 per cent twice, viz., end of June and December. In mature tea (elevation 3200') there are two minima—one at the end of June and a second time at the end of November—after the first and second heavy flush periods respectively.

The tendency to accumulate increasingly their starch reserve from after the middle of January in the case of the stumps is indicated, though this increase is not uniformly maintained. A temporary drop is apparent before the maximum is reached, at the end of May, in the case of the high-elevation

stumps, and nearly three fortnights earlier in the mid-elevation stumps. From the time of reaching the maximum (31st May and 15th April) a decline in reserves follows; this decline extends up to 31st July for the high-elevation and about the 30th June for the stumps from mid-elevation. A second period of rise in reserves is indicated after this time and once again we find the high-elevation stumps reaching their second peak in the middle of September, while mid-elevation stumps reach their maximum at the end of July. From then on, there are frequent fluctuations and the curve movements appear to run more or less on parallel lines. Roughly therefore, there are two periods when starch reserves are highest and the time varies in the two cases under discussion.

The seasonal fluctuation tends to be more even in the high-elevation stumps. In the low elevation stumps the variations are rapid and unsteady. It is likely that this unevenness is due in a large degree to climatic changes and the consequent reaction on the metabolic functions. Since growth is more rapid and temperatures are higher—both these factors possibly influence quicker depletion and the accumulation of reserves in the mid-elevation. The possibility of climatic conditions not allowing much scope for larger accumulation of reserves (because of rapid growth) is suggested as an explanation of the consistently low reserve figures obtained in this case. This is apart from the jat tendency that should also be a factor in any such determinations.

The more equable climate, and therefore even growth or slower growth during particular months may account for the substantially higher figure for reserves indicated in the stumps from the high elevation.

On the assumption that success in supplying is dependent on the plants having *sufficient reserve material*, it is apparent from the presented data there can be no uniformity in time of planting in the two different elevations. The present indications suggest that at the higher elevations failures due to lack of reserves are less likely to occur. It is only between the second fortnight in June and the middle of August that the reserves are low. However, in the high elevations it is possible that in spite of greater reserves during the entire season, enzymatic action necessary for rendering starch available for use is restricted because of low temperatures at certain periods of the year. Considered from this aspect supplying, as early as possible in the season would appear to be advantageous.

At mid-elevations the maximum reserves are reached by mid-April followed by a rapid depletion after this period. Temperature as a limiting factor for growth does not occur at mid or low-elevations. From the reserves point of view it is evident that planting should be done as early as possible (February to April). Where practicable the advantages of obtaining supplies of stumps from the high elevations for planting in mid or low-elevations may be considered.

Starch variations in Mature Tea.—Brief mention on the relation between pruning and starch reserves was made in the report for last year (1939-40). Further work has been progressing and the changed methods indicated in the procedure that is being adopted for stumps have also been under trial for roots from mature tea. The results here given relate to the visual (iodine test) method of determining starch. Table 2 below gives the periodic values obtained for starch,



FIG. 2.

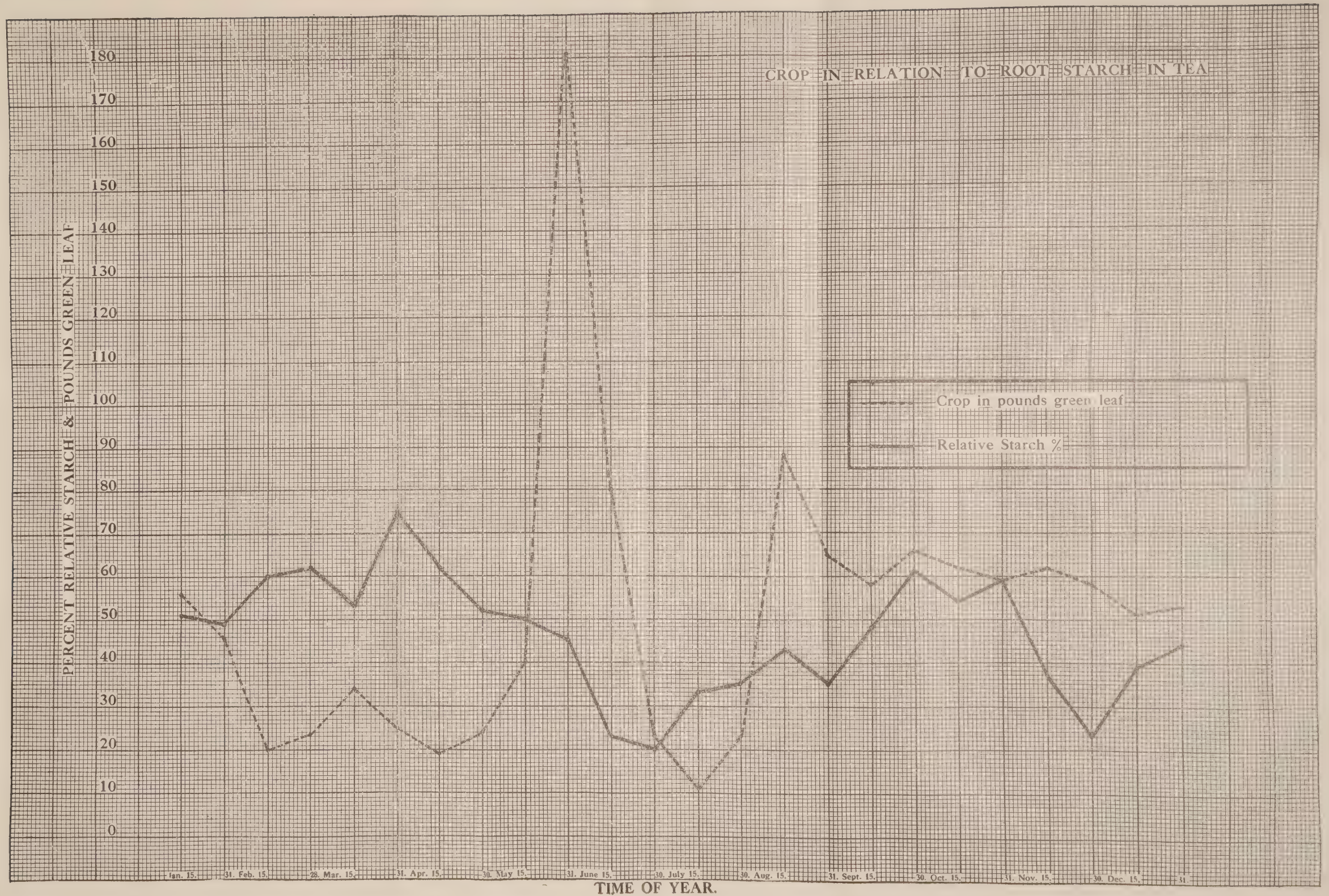


Table 2.—*Average fortnightly variation in root starch (visual) and its relation to Crop in Mature Tea*

Month	First Fortnight (15th)		Second Fortnight (30th)	
	% Starch	Lbs. Crop	% Starch	Lbs. Crop
January ...	51·6	56·25	49·2	45·50
February ...	60·0	20·25	62·4	23·50
March ...	53·2	34·25	75·2	25·00
April ...	62·0	19·00	52·4	24·25
May ...	50·0	40·75	45·2	181·50
June ...	23·6	80·25	20·4	22·75
July ...	33·6	11·25	35·6	23·25
August ...	42·8	87·75	35·0	65·50
September ...	48·0	57·87	61·0	66·00
October ...	54·4	61·50	58·8	60·00
November ...	36·8	62·00	22·8	58·50
December ...	39·6	51·50	44·0	53·50

For purposes of comparison, the starch values for stumps have been shown together with the values for mature tea roots (Fig. 1). In the second curve (Fig. 2) starch values for mature tea alone are given in relation to the crop.

Comparing the variations in starch in stumps and in mature tea roots (Fig. 1), it is apparent that the general trend of the curve for mature tea follows almost similar lines. The starch accumulation is on the increase from January reaching its maximum on 31st March. This increase is followed by a steady depression in starch content the minimum being reached on 30th June. A second but a less marked accumulation occurs from July and the peak accumulation is reached at the end of September. The accumulated reserves up to 30th September are not apparently very much disturbed for one more month—31st October—after which there is the second fall in reserves and this fall ends with November. From the beginning of December there is again a rise which is arrested only at the end of March.

In N.E. India (I.T.A. Rept. 1930, pp. 99-101, 1931) a drop appears to occur from January to June, but increases from July to October reaching its maximum in November—December. In S. India the period of rise varies and occurs from December to end of March; the second period of accumulation begins from July and may end either in August or September perhaps according to climatic conditions.

Tentatively then, pruning between the months of March and April may ensure greater chances of success by minimising die-back or failure to recover from pruning. Although the recorded observations show a second rise later in the season and at the end of the wet weather it seems that this period is subject to great fluctuations, the increase occurring either earlier or later according to the earlier and prevailing climatic conditions. In other words the time of the second pronounced flush period appears to be a variable factor.

Relation of Crop to Starch.—That the accumulation of reserves has also a bearing on growth or flush periods is shown in Table 2 from which

data for Fig. 2 has been drawn. Increased crops result in a depletion of the reserves although there does not appear to exist any quantitative relation. From January up to the middle of April there is little crop harvested and just at this time there is an accumulation of starch reserves. The maximum accumulation for the season occurs at the end of March and about three fortnights earlier than the peak flush period (31st May). After the first peak flush the depletion continues till the end of June. From the beginning of July the roots again seem to store up starch reaching a maximum at the end of September. The crop also begins to show an increase about this time but with apparently very much less depletion of reserves (there is an indication of a small drop in starch on 31st August). The 2nd peak crop has its culmination about the middle of August and from then more or less even crops are maintained till the end of the year. Usually the 2nd peak in crop occurs during the latter part of September or early in October. The variation here noticed has perhaps been influenced by climatic conditions.

The behaviour of the bush both as regards crop and starch at the time of the second flush in the rainy season appears to be peculiar. Tunstall (I.T.A. Ann. Rept. pp. 39-50, 1932) observes a similar discrepancy in the rainy season but is also unable to explain the cause of this behaviour. This as yet unexplained position continues till the end of October. Later, however, the crop relation to starch is maintained, i.e., the larger crop is associated with a drop in reserves till again the position becomes reversed (during dry weather) in the direction of more starch and less crop beginning with January.

One conclusion that may be drawn is that after the heavy flush when the starch reserves are low, pruning tea may be a disadvantage. Pruning according to the data obtained is not advisable after April and to the end of June. But as the second peak flush comes in so soon after the first, the drain on the vitality of the bush may be great if tea is pruned before the second peak flush or immediately after it.

The analytical method of determining the total carbohydrate has given valuable results so far and further work on the subject of root reserves discussed here is progressing. Determinations are being made of root samples from (1) tea normally pruned, (2) tea rested after pruning, and (3) tea rested prior to being pruned at fortnightly intervals. This work will be continued for an entire pruning cycle.

GREVILLEA ROBUSTA

As a result of investigations the defoliation and gradual deterioration of Grevillea trees that were frequently reported from estates in the High Range are attributed to causes other than attacks of the leaf disease organism—*Phyllosticta*. Besides this now well-known agency another fungus *Cercospora* was found. Red spider also occurred. However, no damage in the form of leaf-fall had resulted from the attacks of these organisms. *Cercospora* has apparently not yet found mention in mycological literature as attacking Grevillea.

There was sufficient direct evidence to establish conclusively that the leaf-fall, die-back, branch canker and gummosis were the result of the action of powerful winds, soil conditions and adverse climatic conditions. The long periods of drought that have been a characteristic feature during the past five or six years have contributed *no less* to the gradual deterioration of these

trees. As a general rule the older and wind-beaten trees appeared to be more affected than the young ones or those protected from wind. Grevilleas in the ridges had similarly suffered.

The pathogenic organisms mentioned earlier, while present, do not seem to be the major factors in the causation of the troubles. If anything, they were of a very secondary importance.

Very little can be done in the form of application of fungicides or insecticides generally in the case of diseases of shade trees. Observations in this direction indicated that the Grevillea in this district suffered little from pathogenic troubles (with the exception of root rots), and therefore no need appeared to exist for preventative measure against organismal diseases.

Against wind damage a system of pollarding to convenient heights—about 25 ft.—has been suggested. Such pollarding had been done on some of the estates and with considerable advantage. A recommendation that definite provision for a plan towards maintaining young and mixed shade trees was also made. In any such plan it appeared that Grevillea should still find a prominent place, as this was a more hardy tree than others that have been so far tried in South India.

There are indications that even in the other planting districts the above factors have contributed towards the deterioration of Grevilleas. It is no doubt true that on certain estates (in the very low elevations) the Grevilleas have never done well. The adverse climate, *Phyllosticta*, or other pathogenic agencies might also have added to the troubles in these areas. It is necessary that under such unsuitable conditions for Grevillea growth other shade trees should replace Grevillea.

ALBIZZIA MOLUCCANA

On an estate in the Wynaad defoliation as a result of attacks from *Cercosporella* was recorded. Climatic conditions, when the attack occurred, were very favourable for the fungus. Misty, humid conditions rather than heavy rainfall were a feature of the period.

The pods from the defoliated trees were also heavily infected.

Although the tea in the area had been attacked by *Cercosporella* the infection was not severe.

ERYTHRINA LITHOSPERMA

(Dadaps)

Fresh cuttings of dadaps which were put out some time during the rainy season, were found to be losing leaf during the dry weather on certain of these vegetatively-propagated plants. No organism was found on the branches or on the leaves. The presence of the root-knot nematode did not appear to have materially affected the trees. Root diseases were absent.

Closer observations at the region of the surface of the soil indicated that as a result of shaking by wind the plants had not sufficient chances of establishing themselves permanently. It was also found that the soil where such leaf-fall had occurred was rather rocky. The dry weather had accentuated the troubles and with a deficient root system the plants could not maintain themselves during the hot weather.

CINCHONA

Two to three year old Cinchona plants were found infected by *Armillaria mellea*. This fungus, it is to be noticed, has been recorded earlier (Ann. Rept. 1933-34) as attacking tea, Grevillea and dadaps in the high elevations.

RED GUMS

The presence of a tumor-like growth at the region of the collar on nursery plants was recorded from many estates. The tumor was woody and as far as could be ascertained had not interfered with the growth of these plants. Apparently because of these tumors being mistaken for root-knots caused by eelworms, their presence seems to have been the cause of some concern. However, there was no indication at all to suggest that these woody tumors were caused by any pathogenic agency. The exact cause of such mal-formations is not yet clearly understood.

Acknowledgements.—Thanks are due to the Madras Government Mycologist for confirming the presence of *Cercospora* sp. on the Grevillea foliage collected from the High Ranges; and to the Managers for courtesies extended during visits to their estates.

M. K. SUBBA RAO,
Mycologist.

REPORT OF THE SOIL CHEMIST

1940-41

Composts.—Sixty-six samples of compost were analysed and reported on during the year. The samples were made by various methods—Indore, Lincoln, Fowler and ADCO. Most of them exhibited very good physical texture while the chemical composition varied very widely but was satisfactory throughout. Judged by the carbon-nitrogen ratio, the green material used for composting had decomposed quite well. Some samples were very wet—either too much water had been used during the manufacture or the heaps had been exposed to rain. The analytical figures of the samples as they were received for analysis are given in Appendix I.

Soils.—Sixty-seven samples of soil from mature tea areas were analysed; some for chemical constituents, some for mechanical composition and all for pH. In addition, fifty samples of soil, most of which were intended to be used for nurseries and some from patches where plants had failed to establish themselves, were examined for pH.

Of the soils from mature tea areas, the majority were from estates, from places where tea was growing well and tea was poor. The figures for chemical and mechanical analyses and pH failed to reveal any difference between good and poor areas as might be seen from the figures appended. One striking feature of the mechanical analysis was the very high percentage of 'gravel and stones' varying from 35 to 55.

The pH values of the soils examined for nurseries varied from a low figure of 4.86 to as high a figure as 7.82. It is well known that tea thrives best only in a definitely acid soil and seedlings are very susceptible to changes in the reaction of the soil. Hence it is advisable that the pH value of the soil is ascertained before it is used for nurseries.

The analytical figures of the soil samples on moisture-free basis are given in Appendix II.

Sulphur Application.—It was stated in last year's report that soil samples received from an estate, where tea failed to establish and tea was poor, showed higher pH values on the whole than those from the areas where tea was growing well. After laboratory determinations with these soils, it was recommended that sulphur be applied at the rate of 1,200 lbs. per acre as an experimental measure to a small area. Accordingly, the area was divided into plots consisting of patches where tea was growing well, tea was poor and tea was not established. To one set of plots sulphur was applied in the latter half of May 1940 and another set of plots was kept as control. Soil samples were taken at monthly intervals and their pH values determined. Unfortunately samples were not received after November nor was information available as to how the tea behaved in the different plots after the sulphur application. But a perusal of the pH figures clearly show that sulphur had begun to act quickly, a definite change towards lower figures being noticeable even a month after application in the experimental plots. By November all the experimental plots were distinctly acid in reaction, though the degree of

acidity varied in individual cases. The monthly averages of (1) the experimental plots and (2) the control plots for the top and sub-soils are given in the following table:—

		May	June	July	Aug.	Sept.	Oct.	Nov.
Control	{ Top	7.03	7.16	7.16	6.8	7.00	6.92	6.52
	{ Sub	7.20	7.22	7.20	7.08	7.14	7.14	6.80
Experimental	{ Top	6.97	6.32	5.93	5.57	6.07	6.00	5.27
	{ Sub	7.09	6.41	6.33	6.17	6.51	6.45	5.77

Weeds in Tea.—In order to get an idea of the amount of weeds growing amidst tea, a patch in the old tea area in the Station 0.39 acre in extent was selected and the weeds growing in this patch were pulled out with the roots once a month and weighed. Samples were taken for moisture determination and the dry weights obtained are given in the table below. The area was pruned in November 1939 and weighing of weeds was started in January 1940 and continued till the end of March 1941. The soil adhering to the roots was removed as far as possible with the minimum amount of water. During the dry months there was an appreciable fall in the amount of weeds growing. Practically no weeds grew in March and April. With the advent of showers the weeds began to grow, the amount gradually increasing till the end of August and then began to fall though after the N. E. monsoon period there was a rise again. It is estimated from the figures that about 6.2 tons of green material can be gathered in this way from an acre annually.

Month		Lbs. dry material	Month		Lbs. dry material
January	1940	... 2.5	August	1940	... 43.63
February	"	... 1.1	September	"	... 9.5
March	"	... 0.22	October	"	... 9.0
April	"	... 0.0	November	"	... 8.0
May	"	... 10.0	December	"	... 12.3
June	"	... 32.4	January	1941	... 2.0
July	"	... 12.2	February	"	... 2.0
			March	"	... 0.5

Ratio of Made Tea to Green Leaf.—The determination of moisture in green leaf was made on all plucking days in the Station. The leaf plucked during the morning was weighed at 11 o'clock, thoroughly mixed and sample taken for determining moisture content. The surface moisture adhering to the leaves was removed, with as little delay as possible by means of thin filter paper, by treating individual flush separately and the weight of green leaf taken again. From the loss in weight the percentage of surface moisture is calculated. No doubt a certain amount of withering can take place, especially during dry weather, even while the surface moisture is being removed but the process is carried out with the least delay. The green leaf was allowed to dry in steam oven for seven to eight hours and the dry weight obtained. From these figures the percentage of made tea with a moisture content of 5 per cent is calculated (1) on the wet leaf, and (2) on the leaf after removing surface moisture. The final figures are not yet complete and hence will be given in next year's report. But so far they show (1) that the percentage of surface moisture varies from 0.0 to 18.5, (2) that the percentage of made tea calculated on wet leaf varies from 21.35 to 29.21, and (3) that the percentage of made tea calculated on leaf after the surface moisture is removed varies from 23.03 to 29.73.

Adulteration of Tea.—Twenty-two samples of alleged adulterated tea from various parts of South India and twenty-three samples of pure tea of all grades from estates in Nilgiris and South Travancore were analysed in accordance with the standards given by Dr. Shaw in the *Planters' Chronicle* (December 19th, 1931, p. 628). In the following table are given the figures obtained, together with those recommended by Dr. Shaw, for comparison. The analyses of some more samples of tea will be made during the coming year.

	Dr. Shaw's figures	Alleged adulte- rated samples		Pure Tea	
		Min.	Max.	Min.	Max.
(1) % Ash insoluble in warm dilute nitric acid 1:5	High grades not greater than 0.5 Dust and Fannings not greater than 3.0	.11	1.47	0.0	.11
(2) % Ash soluble in warm dilute nitric acid 1:5	5.0 — 6.0	5.76	8.92	5.28	6.55
		one sample	17.39		
(3) % Soluble solids	Not less than 38	16.6	42.7	42.2	47.8
(4) Iodimetric 'Totals' equivalent	18.00 ccs. N/20 Sod. thio per 0.10 gram dry sample	5.1 ccs.	21.7 ccs.	19.3 ccs.	25.6 ccs.
(5) Soluble Manganese $\times 100$ Total Manganese	Not less than 45	Majority, less than 45		50 or more than 50	

All the samples of genuine tea gave distinctly higher figures for (1) Soluble solids, (2) Totals, and (3) Manganese than the minimum suggested by Dr. Shaw, whereas only a few of the alleged adulterated samples came up to the figures suggested.

Leaching Trials with Decomposing Organic Matter.—In order to get an idea as to how much nitrogen is lost, if it is lost, from dadap, grevillea and tea leaves when these are allowed to decompose, leaching trials were carried from the end of September to the beginning of January. A brief description of the method adopted with a summary of the final figures obtained are given below.

Inside the laboratory known weights (15 lbs.) of leaves of tea, dadap and grevillea, cut into pieces and mixed with 1 lb. of fresh soil, were allowed to decompose in different galvanized zinc reservoirs, the mass being turned once a week to aerate it thoroughly and also watered, the amount of water used depending on the dryness of the mass. The initial nitrogen content was determined before start. At the end of a definite period—three months—the decomposed material was analysed for total nitrogen, nitric, ammoniacal and nitrite nitrogen. The container was washed thoroughly with distilled water and the wash liquid also analysed. The percentage of nitrogen lost and that transformed into various forms was calculated.

Outside the laboratory in a vacant piece of land two sets of experiments were carried out. The reservoirs resting on wooden tripod, were round in form with the sloping sides ending in a small hole fitted with wire gauze and then drawn into a funnel which ended in a bottle placed inside a drum. In one set the green material was allowed to decompose admixed with a small amount of soil. In another, a known weight of soil (80 lbs.) was placed in the container and covered by wire netting over which the green material was placed. The mass was turned once a month. During rains the leachate water drained into the receptacle below. It was collected every day, thoroughly shaken, accurately measured, ten per cent of the total volume kept in a stoppered bottle and analysed at fortnightly intervals, for nitrogen fractions. At the end of three months the residual mass and wash liquid were analysed.

Inside laboratory

	Initial C/N	% of initial nitrogen lost	% of initial nitrogen converted into $\text{NO}_3\text{-N}$	% of initial nitrogen converted into $\text{NH}_3\text{-N}$
Dadap ...	12.3	50.6	9.3	.7
Tea ...	19.1	14.0	5.1	.8
Grevillea ...	36.7	2.3 (gain)	...	.5

Outside laboratory

Material sprinkled with soil.

	% of initial nitrogen lost in gaseous form	% of initial nitrogen converted into $\text{NO}_3\text{-N}$	% of initial nitrogen converted into $\text{NH}_3\text{-N}$
Dadap ...	4.8	11.2	19.6
Tea* ...	1.07 (gain)	14.0	4.5
Grevillea ...	2.6 (gain)	...	...

Material lying on a layer of soil.

	Initial C/N	% of initial nitrogen lost in gaseous form	% of initial nitrogen converted into $\text{NO}_3\text{-N}$	% of initial nitrogen converted into $\text{NH}_3\text{-N}$
Dadap ...	11.8	43.0	16.0	2.2
Tea ...	16.8	9.0	7.5	2.9
Grevillea ...	38.7	7.0	...	...

The following conclusions are drawn from the figures given above and from the leachate water analysis:—

(1) The extent of decomposition would appear to depend on the carbon-nitrogen ratio of the material. Tea forms an exception probably because of its tannin content.

(2) Dadap with high nitrogen content and low C/N ratio loses a large percentage of its nitrogen in gaseous form probably as ammonia, the percentage varying between 24 and 50, the nitric nitrogen formed varying between 9 per cent and 16 per cent of the original nitrogen.

* The residual mass of tea was found to contain a small quantity of excreta of Noctuid caterpillars which could not be completely removed during final analysis. The small gain noticed is presumably due to this.

(3) Tea with a C/N ratio below 20 loses only between 9 per cent and 14 per cent of the initial nitrogen taken. The percentage of nitric nitrogen formed varies between 5 and 14.

(4) *Grevillea* with low nitrogen content and high C/N ratio loses 7 per cent of its initial nitrogen in one case and shows a slight gain in the other two cases. Insignificant amounts of ammoniacal and nitric nitrogen are formed.

(5) Hence when nitrogen-rich materials are allowed to decompose a considerable proportion of nitrogen is lost from the very beginning, most probably as ammonia.

(6) It is only very late, after 45 days, that nitric nitrogen is formed.

It is hoped to continue the trials in the coming year in different forms in different seasons. The final and complete set of figures and conclusions will be published after these trials are completed.

General.—(1) Periodic determinations of ammoniacal and nitric nitrogen in soil from a patch of tea are being made.

(2) A lime sample intended for use in spraying showed 50% sand and only 22.4% CaO.

(3) Seventeen samples of artificial manure mixtures were analysed and found to be either up to or well above the guaranteed analysis.

(4) Two samples of mine-shaft deposit analysed 1.3% and 1.5% nitrogen, 3.3% and 2.3% phos. acid and .61% and .65% potash.

(5) Chemical analysis was made on a sample of water from a neighbouring estate.

(6) Groundnut-cake samples offered for sale by firms showed nitrogen content of 8.4% and 7.61%.

(7) Potash content in a sample of sulphate of potash offered for sale was found to be far below average.

(8) Lime-bearing rock when analysed showed 34.2% CaO while the same rock burnt, slaked and sifted showed 40.1% CaO.

(9) With a view to using it in compost heap a sample of rice husk was analysed. The percentage of nitrogen was .89 and the C/N ratio 51.0.

(10) Jungle soil intended to be used for top dressing had a nitrogen content of 1.09%.

(11) Samples of wattle bark, one kept for several years and the other fresh, were analysed with a view to find out whether any deterioration in tannin content had taken place. The fresh sample showed nearly 53% tannin while the other contained 43%.

(12) Samples of soil from jungle area, cleared land, grass land under cultivation and adjoining grass land, were analysed for nitrogen and organic matter. The soil from jungle area showed .63% nitrogen while that from cleared land showed only .51%. The percentage of nitrogen in grass land soil under cultivation for some years was .27 while that from adjoining area was .297. Curiously, the organic matter extracted by shaking with 4% ammonia

was nearly twice as much in the grass land samples as in the jungle samples. More determinations will be made during the coming year.

(13) To assess its value as a fertiliser, a sample of rice-husk ash was analysed and found to contain 2.19% phos. acid and 2.18% potash.

(14) Mechanical analysis of two samples of soil from the Nanjanad Farm, Ootacamund, was carried out.

(15) The caffeine content of six samples of tea waste, three from North India and three from South India, was determined. The North Indian samples showed 3.36%, 3.24% and 1.77% caffeine while the percentage in the South Indian samples was 1.945, 2.365 and 2.16.

V. JAYARAMAN,
Soil Chemist.

APPENDIX I

SUMMARY OF COMPOST ANALYSES

No. of samples	Moisture %	Loss on Ignition %	Nitrogen %	C/N	Phosphoric Acid %	Potash %
KANNAN DEVANS						
13	62.8	15.2	.52	13.5	.21	1.35
10	68.3	14.3	.46	13.7	.22	.93
1	58.2	16.4	.55	12.7	.23	1.53
1	60.9	14.2	.44	13.2	.30	1.30
2	39.3	16.2	.58	12.1	.32	1.63
1	39.2	14.1	.52	10.0	.345	1.615
1	41.5	16.1	.66	10.6	.30	1.39
1	52.7	13.5	.46	11.5	.29	1.37
SOUTH TRAVANCORE						
1	44.9	18.9	.97	...	.41	...
1	53.7	11.7	.43	12.7	.21	.89
1	59.5	12.2	.40	10.9	.37	1.24
1	48.2	15.0	.46	10.4	.18	.69
1	46.0	14.8	.38	14.2	.20	.91
WYNAADS, NILGIRIS AND MALABAR						
1	46.9	15.8	.55	12.0	.225	.62
1	45.0	14.2	.46	13.0	.26	.51
1	14.1	29.7	1.235	...	.62	1.35
1	32.6	22.5	.90	...	.42	.56
15	52.3	13.6	.475	11.4	.24	.53
ANAMALLAIS AND OTHER DISTRICTS						
6	71.1	14.2	.44	...	.20	.765
2	58.8	12.7	.38	...	.42	1.32
1	52.0	22.4	.68	15.3	.19	1.11
1	40.8	19.2	.59	14.0	.19	1.00
1	46.7	25.7	.76	15.3	.22	1.27
1	65.8	20.3	.66	14.4	.22	1.05

APPENDIX II SUMMARY OF SOIL ANALYSES

No. of samples	Loss on Ignition %	Nitrogen %	Phosphoric Acid		Potash	
			Total %	Avail- able %	Total %	Avail- able %
CENTRAL TRAVANCORE						
1	16.7	.27	.22	.0140	.62	.044
1	12.0	.16	.14	.0064	.57	.041
SOUTH TRAVANCORE						
Tea—						
Good Area						
Top soil 4	13.8	.198	.153	.0094	.352	.031
Poor Area						
Top soil 4	12.1	.208	.128	.0080	.345	.020
Good Area						
Sub soil 4	12.2	.092	.110	.0022	.34	.027
Poor Area						
Sub soil 4	12.4	.104	.132	.0030	.334	.025
Rubber—						
Top soil 1	17.4	.260	.138	.0096	.23	.029
Sub soil 1	15.4	.119	.092	.0033	.25	.030
Tea—						
Good Area						
Top soil 6	14.0	.206	.073	.0052	.32	.031
Poor Area						
Top soil 6	13.4	.200	.084	.0053	.33	.031
Good Area						
Sub soil 6	14.4	.111	.066	.0020	.33	.026
Poor Area						
Sub soil 6	12.3	.112	.074	.0023	.32	.024
Rubber—						
Top soil 2	13.3	.190	.120	.0036	.33	.020
Sub soil 2	12.7	.108	.110	.0020	.27	.025
WYNAADS, NILGIRIS AND MALABAR						
Top soil 6	10.	.110	.084	...	.20	...
Sub soil 6	10.1	.055	.074	...	.19	...
Top soil 2	10.3	.120	.123	...	.275	...
Sub soil 2	9.4	.047	.120	...	.23	...
Top soil 1	11.9	.180	.090	.0075	.21	.037
Top soil 1	11.9	.140	.081	.0102	.23	.024
ANAMALLAIS						
1	17.5	.280	.111	.0061	.38	.062

UNITED PLANTERS' ASSOCIATION OF
SOUTHERN INDIA

TEA SCIENTIFIC
DEPARTMENT

ANNUAL
ADMINISTRATION REPORT

FOR

1940-41

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PRINTED AT THE DIOCESAN PRESS, VEPERY

1941